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Annual Report

Mainstem Clearwater River Study:
Assessment for Salmonid Spawning, Incubation, and Rearing

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ABSTRACT

Chinook salmon reproduced naturally in the Clearwater River until damming of the lower mainstem in 1927 impeded upstream spawning migrations and decimated the populations. Removal of the Washington Water Power Dam in 1973 reopened upriver passage. This study was initiated to determine the feasibility of re-introducing chinook salmon into the lower mainstem Clearwater River based on the temperature and flow regimes, water quality, substrate, and invertebrate production since the completion of Dworshak Dam in 1972. Temperature data obtained from the United States Geological Survey gaging stations at Peck and Spalding, Idaho were used to calculate average minimum and maximum water temperature on a daily, monthly and yearly basis. The coldest and warmest (absolute minimum and maximum) temperatures that have occurred in the past 15 years were also identified. Our analysis indicates that average lower mainstem Clearwater River water temperatures are suitable for all life stages of chinook salmon, and also for steelhead trout rearing. In some years absolute maximum water temperatures in late summer may postpone adult staging and spawning. Absolute minimum temperatures have been recorded that could decrease overwinter survival of summer chinook juveniles and fall chinook eggs depending on the quality of winter hiding cover and the prevalence of intra-gravel freezing in the lower mainstem Clearwater River. Average and absolute summer temperatures during the majority of years since Dworshak Dam operation have been warmer than optimum for chinook salmon and steelhead rearing, but are well below the upper temperatures tolerated by these species. Dworshak Dam flows could influence anadromous fish spawning, incubation, and rearing, however, more information on lower mainstem Clearwater River habitat is needed to quantify flow effects. Water Quality in the lower Clearwater is suitable for all life stages of chinook salmon and steelhead trout. Information on Clearwater River substrate is inadequate to discuss its suitability for spawning and rearing of anadromous fish. Aquatic invertebrate production appears to be adequate to rear both juvenile steelhead trout and chinook salmon.

INTRODUCTION

Historically, large numbers of salmon (Oncorhynchus sp.) and steelhead trout (Salmon gairdneri) spawned and reared in the Clearwater River Basin (Figure 1). However, documentation of the species/race composition and numbers prior to Columbia Basin impounding is limited mostly to eye-witness accounts. Lane and Lane Associates, and Nash (1981) interviewed Nez Perce Tribal elders regarding nineteenth and early twentieth century fishing activities. Apparently, steelhead trout fishing began in November and continued until June when fish became soft and unpalatable. Salmon arrived in July, were caught in August through September until they died after spawning at the heads of "smaller tributaries" (Wilson in Lane and Lane Associates, and Nash 1981). There was no mention of lower mainstem Clearwater River (LMCR) spawning or fishing efforts; perhaps because tribal fishing technology was not geared towards fish harvest in this large mainstem river.

The timing of migration, spawning, and harvest efforts strongly suggests that summer/spring runs of chinook salmon (O. tshawytscha) and summer steelhead trout were the principal taxa of anadromous fish in the headwaters and tributaries of the Clearwater River. Also, coho (O. kisutch) (Slickpoo in Lane and Lane Associates, and Nash 1981) and fall chinook salmon (Richards 1967) may have inhabited the drainage. Interviews conducted by Lavier (1976) suggest that prior to 1850 fall chinook salmon spawned from the Snake River confluence to the present location of Orofino.

Chinook salmon and steelhead trout runs declined below historic levels by 1915 (Kipp in Lane and Lane Associates, and Nash 1981). Inadequate fish passage at the two Washington Water Power Dams (WWPD), at Lewiston in 1927 and Stites in 1949, further reduced steelhead trout populations and virtually eliminated chinook salmon runs (Richards 1967). Sporadic fish counts at the Lewiston WWPD from 1928-1950 indicate that summer steelhead trout and chinook salmon comprised the surviving anadromous run (Richards 1967). Notably, counting times and procedures were not designed to detect the presence or absence of fall chinook or coho salmon (Richards 1967).

Murphy and Kieffer (in press) authored a detailed review of anadromous fish releases in the Clearwater River subbasin. Apparently, the Idaho Department of Fish and Game (IDFG) began supplementing depressed anadromous runs by planting a total of 250,000 spring chinook fingerlings in the Little North Fork of the Clearwater River between 1947 and 1954 (Richards (1967)). When fish passage by the

Lewiston WWPD was improved in 1961 (Welsh 1961), IDFG initiated a chinook salmon restoration program directed primarily towards re-establishing a self-sustaining run of fish in the Selway River system. Eyed egg plants of fall (Snake River and Spring Creek, Washington stocks)(Welsh 1961) and summer/spring chinook salmon (Salmon River, Carson National Fish Hatchery Washington, and mixed stocks from Bonneville Dam trapping operations) (Welsh 1963) were started in 1960 and 1961, respectively. The total number of eggs planted in the Selway during the reintroduction program totalled 61.9 million (Lindland and Bowler 1986).

Efforts were also made to restore coho salmon runs above the Stites WWPD on the South Fork Clearwater River using Abernathy Hatchery Washington stock in 1962 (Richards 1967). In 1963, this WWPD was removed, thereby easing passage to the South Fork (Bell 1964).

Attempts to restore fall chinook and coho salmon in these Clearwater River tributaries were terminated in 1968 due to poor adult returns (Hoss 1970a and 1970b). Also, it appears that by 1972 summer chinook egg plants and releases had been virtually eliminated (Hoss 1972).

On the other hand, spring chinook salmon restoration efforts expanded in the 1970's to include the Lochsa River and Lolo Creek (Lindland and Bowler 1986). Approximately 3.5 million spring chinook salmon fry and smolts (Rapid River, Carson, South Santiam, Little White Salmon and Leavenworth Hatchery stocks)(Howell et al. 1985) were released in the Lochsa River drainage from 1972 to 1979 (Lindland and Bowler 1986). One hundred thousand and five hundred Rapid River spring chinook salmon fry were released into Lolo Creek in 1970. Spring chinook restoration has continued through the 1980's, predominantly in the South Fork Clearwater River (Lindland and Bowler 1986).

The success of the IDFG chinook salmon restoration program was measured by adult counts at the Lewiston WWPD from 1950-1972 and by redd counts and regression analysis from 1973-1985 (Lindland and Bowler 1986). According to Lindland and Bowler, spring chinook runs to Clearwater River headwaters increased from 1950 from a low of nine to a high of 3,467 adults. Regression estimates for the years 1972 to 1985 averaged 2,780 spring chinook adults to Clearwater River headwaters (calculated using data in Lindland and Bowler 1986, excluding Kooskia National Fish Hatchery releases).

Smolt and fry releases from Kooskia National Fish Hatchery (KNFH) contribute to spring chinook salmon returns to the Clearwater River. Kooskia NFH is owned by the U.S. Fish and Wildlife Service and is operated to supplement spring chinook stocks primarily by direct releases into Clear Creek. Approximately 6.5 million smolts and 4.5 million fry were released into Clear Creek from 1971 - 1985, but relatively few smolt outplants have been made into the habitat (Lindland and Bowler 1986). Adult returns to the rack during this time period have ranged from 5 to 3,026 fish (Miller et al. 1987).

Steelhead trout return to the Clearwater River in greater numbers than chinook salmon. Adult wild steelhead counts at the Lewiston WWPD ranged from 3,167 to 22,514 from 1950 to 1961 (Miller 1987). Nonetheless, the Stites WWPD combined with other pollution problems necessitated steelhead supplementation efforts in the South Fork Clearwater River. Steelhead gametes were taken at the Lewiston WWPD to controlled hatching channels on the South Fork beginning in 1962 (Richards 1967). Although this program continued through the early 1970's it was impossible to quantify adult returns to the South Fork because of high turbid runoff common during the steelhead spring spawning period (Hoss 1971, 1974, 1975). Notably, total passage at the Lewiston WWPD averaged 22,428 fish during the 1962 to 1972 time period (calculated using data from Miller 1987) prior to the damming of the North Fork Clearwater River.

The damming of the North Fork Clearwater River by the U.S. Army Corps of Engineers in 1970 caused a profound change in Clearwater River steelhead management. Dworshak National Fish Hatchery (DNFH) was constructed by the U.S. Army Corps of Engineers to mitigate the loss of steelhead trout produced in extensive prime spawning areas flooded and blocked by Dworshak Dam (Figure 1). One and a half to approximately 2.8 million smolts (Lindland and Bowler 1986) of North Fork summer run steelhead trout ancestry (Dworshak Hatchery stock) are released annually in the Clearwater River subbasin, primarily in the spring. Dworshak NFH relies on adult returns to the rack for perpetuation of production operations. Dworshak NFH also contributes a spring chinook salmon and summer steelhead trout eggs, fry, smolts, and adults to Clearwater River headwater and tributary supplementation efforts when surplus adults return to the hatchery.

Conclusive quantification of steelhead returns to the Clearwater ended when Lewiston WWPD was removed in 1972. However, steelhead escapement estimates are available for both hatchery and wild fish. Miller (1987) estimated that hatchery returns to the river, including tribal and sport harvest, has ranged from 1,988 to 37,628 adult steelhead trout during the 1972 to 1987 time period. Wild steelhead escapement estimates to the Clearwater River are based on adult counts over Lower Granite Dam on the Snake River less Snake River drainage escapement, Clearwater River sport fishing harvest and DNFH rack returns (Lukens 1982). Lukens (1982) reported wild fish return estimates as high as 8,440 fish or 41.5% of the total run. Wild steelhead trout may constitute as high as 60% of the total escapement to the Clearwater River in a given year.

Anadromous salmonid restoration, supplementation and mitigation efforts in the Clearwater River Basin are obviously complex. However, in this brief review we have shown that all attempts to restore and supplement natural salmon spawning have been in the headwaters of the Clearwater and few of these efforts involved smolt outplanting. Management in the lower mainstem Clearwater River has revolved around hatchery mitigation for the loss of North Fork steelhead and Lower Snake River Compensation Plan production.

Surprisingly, there have been no efforts to restore natural mainstem chinook salmon production to the lower 70 kilometers (42 miles) of the Clearwater River, perhaps because of the concentration of management efforts on the more pristine headwaters of the basin. Likewise, there has been little effort to document the use of this river reach by rearing juveniles produced naturally in these headwaters or the effect of Dworshak Dam operations on anadromous salmonid habitat in the LMCR.

Restoring natural spawning runs of chinook salmon and perpetuating hatchery chinook salmon and steelhead trout runs through smolt and fry releases will be instrumental in accomplishing the Northwest Power Planning Council's goal of doubling the existing salmon and steelhead runs in the Columbia River system by 1992. The attainment of this goal will require a thorough knowledge of the production potential of Columbia River tributaries. Accordingly, the Nez Perce Tribe in cooperation with Bonneville Power Administration, will implement measure 703(c)3 of the Columbia River Basin Fish and Wildlife Program to assess: 1) the opportunity to restore naturally spawning populations of summer and fall chinook salmon in the lower Clearwater River subbasin; and 2) the feasibility outplanting chinook salmon and steelhead trout.

This annual report:

- 1) Evaluates the temperature regime of the Lower Mainstem Clearwater River for summer and fall chinook salmon spawning and incubation since completion of Dworshak Dam;
- 2) Estimates the time of emergence of summer and fall chinook salmon in the Clearwater River based on post-Dworshak Dam temperature data;
- 3) Analyzes post-Dworshak Dam daily summer maximum temperatures to determine their impact on rearing of chinook salmon and steelhead trout;
- 4) Determines the likelihood of successful summer and fall chinook smoltification and outmigration to the Lower Snake River given the current Water Budget and LMCR temperature and flow regimes since the operation of Dworshak Dam;
- 5) Analyzes the post-Dworshak Dam flow regime to determine its impact on potential spawning and rearing in the lower mainstem Clearwater River; and
- 6) Reviews the scientific literature on the water quality, substrate, and invertebrate fauna of the lower mainstem Clearwater River and discusses the relevance of this information to restoring mainstem anadromous spawning and assessing mainstem rearing potential.

STUDY AREA

The lower mainstem Clearwater River (LMCR) flows almost entirely within the Nez Perce Reservation (Figure 1). The LMCR originates at the confluence of the mainstem Clearwater and the North Fork of the Clearwater River, 6.7 km (RM 4.9) downstream from Orofino, Idaho.

Lower mainstem Clearwater River discharge and temperature regimes are largely determined by natural inflow from the Middle Fork, South Fork, and dam regulated flows from the North Fork of the Clearwater River. Ten major tributaries also supply the LMCR with water (Figure 1).

This report evaluates anadromous salmonid production potential from the confluence of the North Fork and mainstem Clearwater 70 km (42 mi) downriver to Lewiston Bridge. Some habitat features of the North Fork of the Clearwater River below Dworshak Dam are also reviewed.

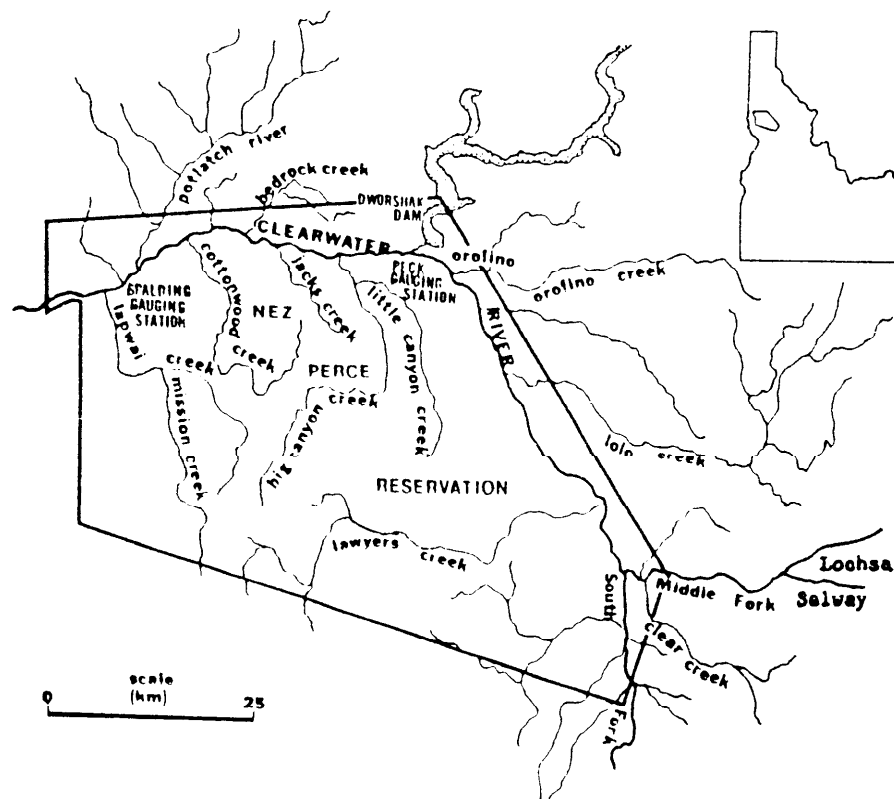


Figure 1. Clearwater River drainage and the location of major tributaries, landmarks, and the United States Geological Survey gaging stations at Peck and Spalding, Idaho (modified from Kucera and Johnson 1986).

METHODS

Assessing the Suitability of LMCR Water Temperature for Anadromous Salmonid Production

Temperature Data Collection and Analysis

The United States Geological Survey (USGS) at Boise, Idaho provided raw temperature data (24-h minimum and maximum water temperature recorded to the nearest 0.50 °C) from the Peck gaging station for the water years October 1972 - August 1987 and Spalding gaging stations for the water years October 1972 - September 1986. These data are summarized in several formats in this report (Appendix A, Tables A1-8). The following definitions are provided for clarification.

Average daily minimum temperature - the average temperature for each day of the year calculated using the actual minimum temperature recorded by USGS for that day from 1972-1986/7.

Average daily maximum temperature - the average temperature for each day of the year calculated using the actual maximum temperature recorded by USGS for that day from 1972-1986/7.

Average monthly minimum temperature - the overall monthly minimum temperature for the time period from 1972-1986 calculated using the average daily minimum temperatures of each month.

Average monthly maximum temperature - the overall average monthly maximum temperature for the time period from 1972-1986/7 calculated using the average daily maximum temperatures of each month.

Absolute minimum temperature - the coldest single temperature recorded by USGS for each month during the entire time period from 1972-1986/7.

Absolute maximum temperature - the single warmest temperature recorded by USGS for each month during the entire time period from 1972-1986/7.

Minimum monthly temperature - the single coldest temperature recorded by USGS for a specific month of a specific year.

Maximum monthly temperature - the single warmest temperature recorded by USGS for a specific month of a specific year.

Separation of River Reaches by Temperature

Average daily temperature values were calculated for the river at Peck and at Spalding to compare the annual temperature regimes. Data from October 1972 to September 1984 were used because these time periods shared common data gaps. A two-sample t-test (Zar 1984) was used to test for statistical difference in the average monthly temperature values from each gaging station.

Stock Selection

Outplanting stocks of summer and fall chinook salmon for temperature assessment were identified by reviewing the literature (Howell et al. 1985, Bjornn 1969, Horner and Bjornn 1981, Irving and Bjornn 1980). The primary criterion governing stock selection for this report was proximity of stock origin to the Clearwater River.

Life stage periodicity for the selected stocks was aligned with absolute minimum, absolute maximum, average minimum, and average maximum temperature regimes of the LMCR at Peck and Spalding, Idaho. Average daily temperature data for the day of the year corresponding to the time of peak spawning for each stock reported in the literature were used as a starting point for accruing temperature units for incubation, where:

1 degree C above 0 °C per day = 1 temperature unit (tu)

Since tu requirements for emergence varies with incubation temperature (Lietritz and Lewis 1980, Piper et al. 1982) water temperature at time of peak spawning was identified and incubation tu requirements were specified accordingly.

Defining Zones of Thermal Tolerance for Chinook Salmon and Steelhead Trout

The United States Fish and Wildlife Reference Services, located in Fort Collins, Colorado and Rockville, Maryland provided a list of references relevant to life stage temperature requirements of chinook salmon and steelhead trout. Computer listings provided by these services were used to conduct a thorough review of the literature pertaining to spawning, incubation, rearing, movement and outmigration of fall and summer chinook salmon and rearing, movement and outmigration of spring chinook and summer

steelhead trout. Publications that specified tolerable temperatures were used to define temperature tolerance for each species of anadromous salmonid being evaluated.

Water Temperature and Fish Tolerance

Time periods identified as having high or low absolute maximum or minimum water temperatures outside of the established zones of thermal tolerance were broken down by year to determine the frequency and duration of unsuitable temperature occurrence. This was done by isolating the maximum or minimum monthly temperature recorded by the USGS for each month of each year, the number of consecutive days the temperature occurred, and the corresponding daily minimum or maximum temperature that occurred the day of the critical temperature.

Effects of Late Summer Water Temperature on Fish Growth

Juvenile chinook salmon and steelhead trout growth during summer periods of suboptimum water temperatures were evaluated by calculating Mean Weekly Average Temperature (MWAT) (Armour unpublished manuscript) where:

$$MWAT = OT + \frac{UUILT - OT}{3}$$

and: OT = a reported optimum temperature for the particular life stage of function.

UUILT = the upper temperature for which tolerance does not increase with increasing acclimation temperatures.

When the average weekly water temperature exceeds the MWAT calculated for a given life stage decreased growth can be expected.

Successful Outmigration from the Clearwater into the Upper Snake River

Growth to critical smolt size:

Estimation of size of age-1+ juvenile summer and age-0 fall chinook at the critical smolting period was done using the method of Armour (1988) where:

$$\text{Monthly growth (mm)} = \frac{\text{Avg monthly water temperature} - 0^\circ\text{C}}{\text{tu's required for 1 mm growth}}$$

Since growth rate data was not available for summer or fall chinook salmon in the Clearwater River, McCall Hatchery data were used. The number of temperature units required for a summer chinook juvenile to grow 1 mm was estimated at 0.82 °C (Tom Frew, personal communication). Fall chinook growth data for fluctuating water temperatures were not available, therefore McCall data was used to estimate fall chinook growth.

Summer chinook growth was not calculated for the months of December, January, and February, and March, since juvenile chinook become dormant and hide in the gravel when water temperatures are below 5.0 °C.

Flows accommodating migration:

Information pertaining to current Water Budget augmentation obtained from the Fish Passage Center was used to assess the likelihood of summer and fall chinook passage by Lower Granite Dam on the Snake River. Clearwater River Discharge at the estimated time of fall chinook salmon emergence was also evaluated for outmigration effects.

Assessing the Suitability of Dworshak Dam and Natural Flow on Anadromous Salmonid Production in the LMCR

The United States Geological Survey (USGS) Boise, Idaho provided raw flow data (24-h minimum and maximum water discharge recorded to the nearest cubic foot per second) from the Orofino, Peck, and Spalding gaging station for the water years 1973 - 1987 and Spalding gaging stations for the water years 1973 - 1986.

The United States Army Corps of Engineers supplied the United States Fish and Wildlife Federal Assistance Office (FAO) daily Dworshak Dam Discharge Data for the time period 1981 - 1985. We obtained this data from the FAO.

Assessing the Suitability of LMCR Water Quality, Substrate, and Invertebrate Production for Anadromous Salmonid Production

We reviewed the literature for scientific research previously completed on the LMCR. A literature review on the habitat needs of spawning, incubating, and rearing chinook salmon and rearing steelhead trout was also completed. This information was summarized to establish the suitability of the LMCR for anadromous production and to identify current research needs.

RESULTS AND DISCUSSION

Assessing the Suitability of LMCR Water Temperature for Anadromous Salmonid Production

Peck and Spalding Water Temperatures

Average daily minimum water temperatures at Peck were significantly cooler ($\alpha = 0.05$) than average minimum water temperature at Spalding (Table 1). Average maximum daily water temperatures calculated from Peck and Spalding gaging station data were not statistically different at the 0.05 level of significance. However, Peck maximum daily temperatures are significantly cooler than Spalding maximum daily temperatures at the 0.10 level of significance (Table 1) 1

Table 1. Comparison of average minimum and maximum weekly water temperatures ($^{\circ}\text{C}$) from October 1972 - September 1984 at United States Geological Survey gaging stations at Peck and Spalding on the Clearwater River, ID using a two sample t-test.

<u>Mean</u> <u>minimum temperature</u>		<u>p-value</u>	<u>Mean</u> <u>maximum temperature</u>		<u>p-value</u>
Peck vs	Spalding		Peck vs	Spalding	
8.1 <	8.7	0.02<p<0.05	9.1 <	9.7	0.10>p>0.05

Average daily Peck water temperatures are not consistently cooler than Spalding temperatures. Beginning the third week of December through late January to early February the temperature regime at Peck is warmer than that of Spalding (Figures 2 and 3). This trend reverses after early February and Spalding waters remain warmer through spring, summer, and fall (Figures 2 and 3).

Gordon et al. (1970) predicted that Dworshak Dam operation would warm the LMCR winter flows and cool the LMCR during summer. Later studies confirmed this temperature alteration (Ball and Cannon 1974, Ball and Pettit 1974, Pettit 1976, Brusven and Haber 1981). Pettit (1976) reported warmer winter temperatures and colder summer temperatures in upper reaches of the LMCR than lower reaches. He suggested that the magnitude of such temperature alteration depends on the volume of discharge from the dam.

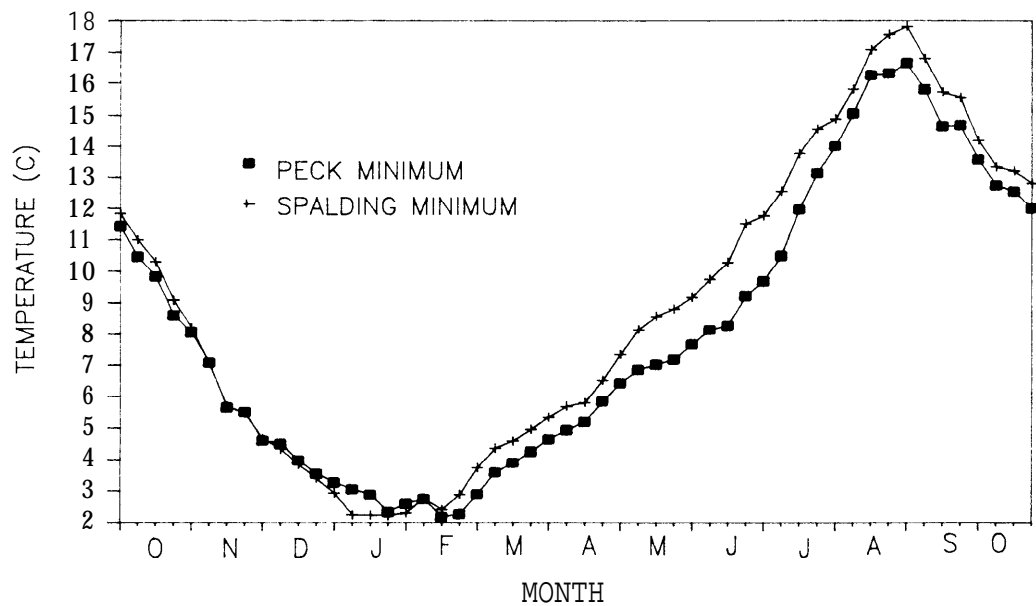


Figure 2. Daily average lower mainstem Clearwater River minimum water temperatures calculated using data recorded by the United States Geological Survey, at Peck and Spalding gaging stations October 1972 - September 1984.

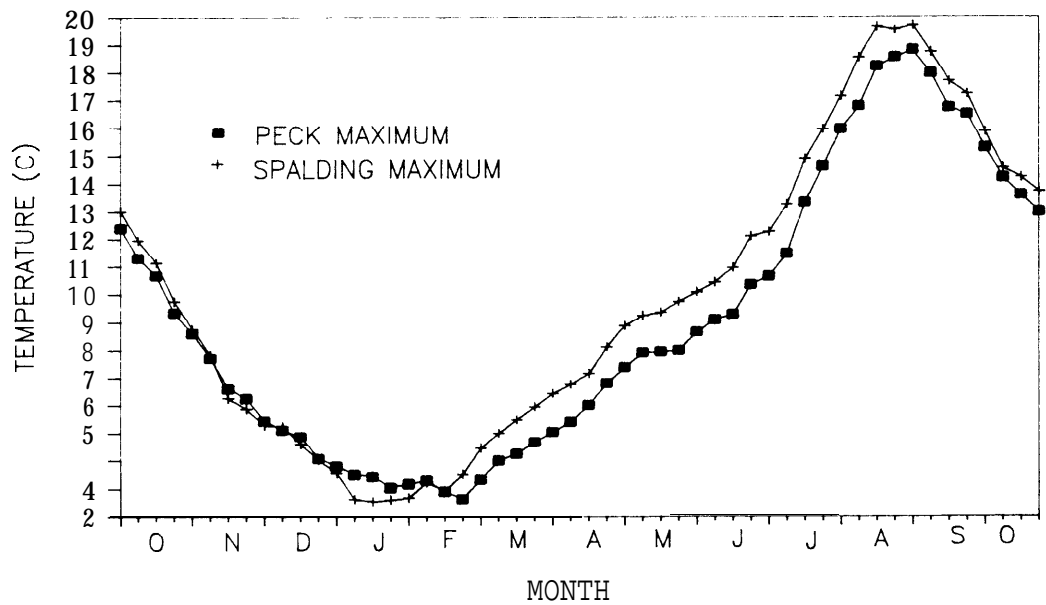


Figure 3. Daily average lower mainstem Clearwater River maximum water temperatures calculated using data recorded by the United States Geological Survey, at Peck and Spalding gaging stations October 1972 - September 1984.

Our analysis of LMCR water temperatures at Peck and Spalding gaging stations confirms perpetuation of warmer winter water and colder summer temperatures through 1984. Also, the difference in water temperature between an upriver site (Peck) and a down river site (Spalding) is concurrent with the temperature difference reported by Pettit (1976). However, a conclusive description of the relationship between Dworshak Dam discharge and the LMCR temperature Regime is unavailable. The ability to predict the effect of various Dworshak Dam discharge volumes on downriver water temperatures would be a valuable management tool.

Stock Selection

The life cycles of Rapid River, South Fork Salmon River, Upper Salmon River, and Upper Columbia River summer chinook and Bonneville Upriver Bright, Deschutes River, John Day, Umatilla, Grande Ronde River, Upriver Bright, and Snake River fall chinook were reviewed during our research. South Fork Salmon River summer and Snake River Fall chinook salmon stocks (Table 2) were chosen to assess LMCR water temperature suitability based on the proximity of stock origin to our study area.

Late August spawning summer chinook and mid-November spawning fall chinook emergence requirements were estimated as 600 and 1,000 tu respectively (Table 2).

Table 2. Life stage periodicity and temperature unit requirements for egg incubation of South Fork Salmon River Summer and Snake River fall Chinook as reported by Howell et al. 1985.

Race	Staging period	Spawning period	Temperature units for incubation (°C)	Duration of freshwater residence (size mm)
Summer	Late June to Mid-July	Late August to mid-September	600	Smelt during second year of life (102-127)
Fall	August through September	Late October through November	1,000	Smolt during first year of life (70-80)*

*Information based on Lyons Ferry Hatchery fall chinook

Zones of Thermal Tolerance for Chinook Salmon and Steelhead Trout

Piper et al. (1982) reported that chinook salmon spawn successfully at 0.6 °C. No information was given pertaining to frequency or duration chinook can tolerate such a low water temperature. Coutant (1970) acclimated jack chinook salmon 3-d at 17.0 °C then raised the water temperature to 22.0 °C. Coutant proposed that the incipient lethal temperature of adult chinook salmon is between 21.0 and 22.0 °C based on the finding that nine of fourteen fish died after exposure for 7-d.

Results from laboratory studies were used to establish the upper and lower temperatures tolerated by incubating chinook eggs. Experiments done by Combs (1965) were used to establish minimum tolerable temperature. This researcher showed that chinook eggs incubated at 5.8 °C for 6-d tolerated 1.7 °C for the duration of incubation with losses of approximately 10% mortality. Research done on Priest Rapids mainstem spawning fall chinook by Olson and Foster (1965) was used to identify an upper temperature tolerated by incubating chinook eggs. Results indicated that eggs could begin incubation at 16.1 °C without significant mortality.

Experiments on young chinook salmon were used to establish the lower limits of temperature tolerance for juveniles (Brett 1952). Results from this study, indicated that 47.0 mm chinook fry reared in 10 °C water suffered less than 50% mortality upon exposure to water temperatures approximately 0.8 °C. The same study documented upper tolerable temperature limits. All young chinook acclimated to 10.0 °C water exposed to 25.1 °C water died within 7-d.

A similar strategy was used to define temperatures tolerated by rearing juvenile steelhead trout. Bell in Bjornn and Reiser (unpublished manuscript) identified lower and upper tolerable temperatures as 0.0 °C and 23.9 °C respectively. No acclimation periods or exposure durations were given.

Information from these studies (Table 3) was compiled to define a zone of thermal tolerance for chinook salmon from staging through early rearing (Figure 4) and for pre-smolt chinook salmon and steelhead trout during late summer rearing (Figures 5 and 6).

Table 3. Maximum and minimum tolerable water temperatures (°C) defined by the literature for eggs/pre-emergent fry, pre-smolt juveniles and adult chinook salmon and pre-smolt steelhead trout.

Species	Life stage	Tolerable temperature	
		maximum (citation)	minimum (citation)
Chinook	eggs/sac fry	16.1 (Olson & Foster 1955)	(Combs 1965)
	pre-smolt	25.1 (Brett 1952)	(Brett 1952)
	adult	21.0-22.0 (Coutant 1970)	(Piper et al 1982)
Steelhead	pre-smolt	23.9* (Bell 1984)	2.0* (Bell 1984)

*Cited in Bjornn and Reiser (unpublished manuscript).

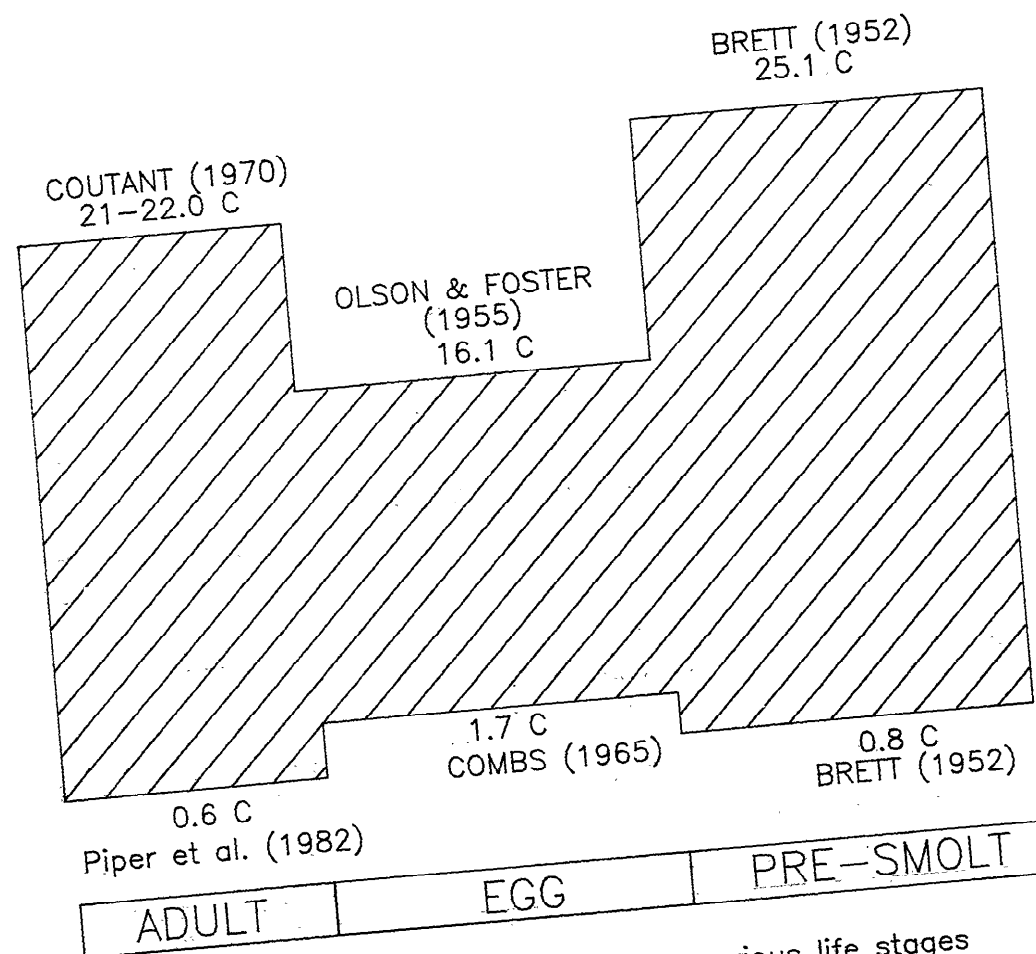


Figure 4. Zone of thermal tolerance for various life stages of chinook salmon as defined in the literature.

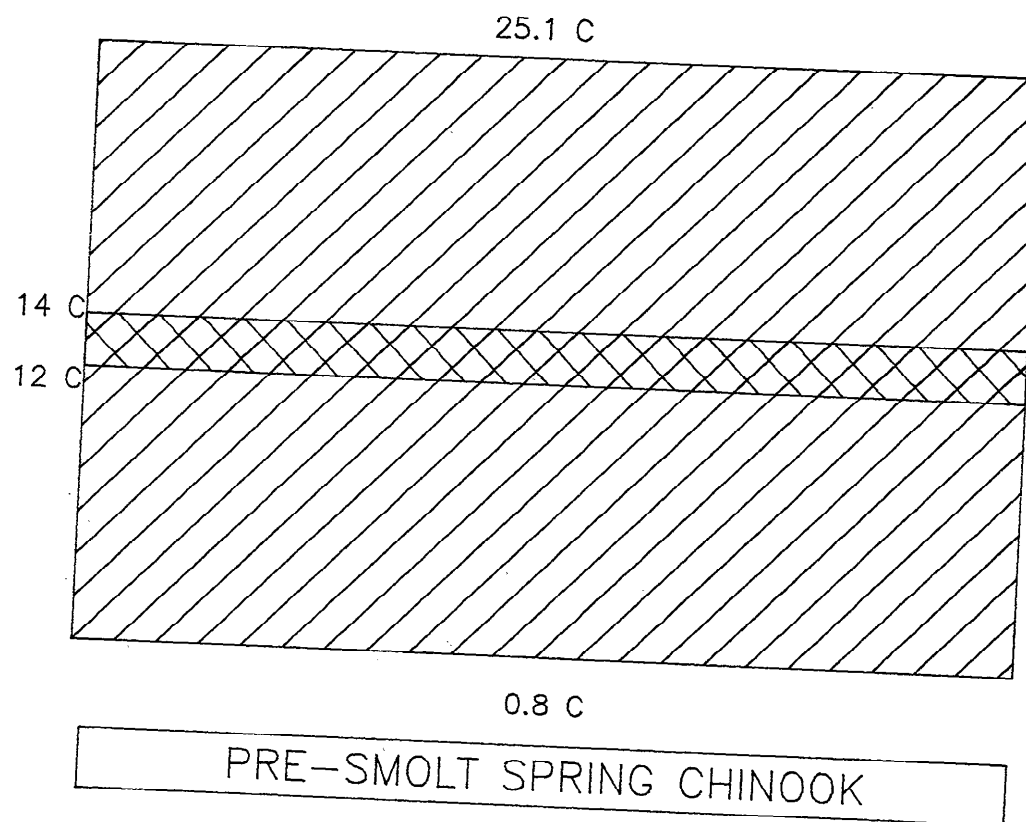
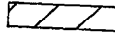
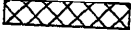


Figure 5. Zone of tolerable  and optimum  temperatures for chinook salmon rearing as defined by Brett (1952).

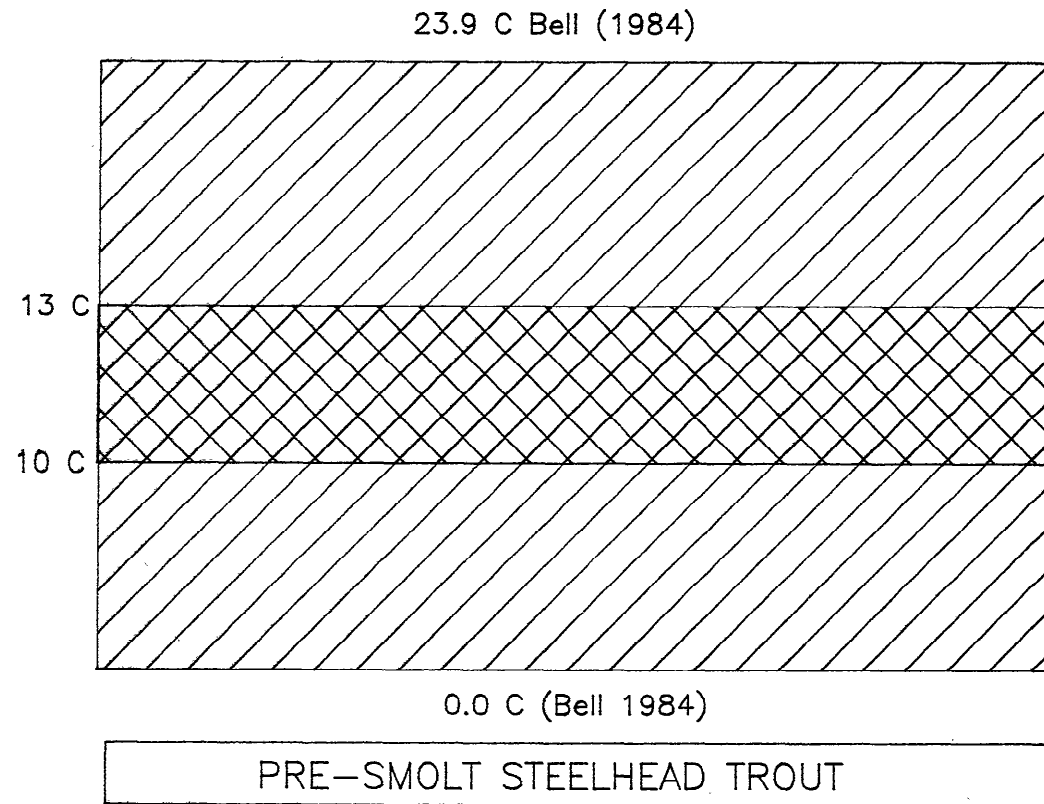


Figure 6. Zones of thermal tolerance and optimum rearing temperatures for steelhead trout defined in a study cited by Bjornn and Reiser (unpublished manuscript).

Suitability of LMCR Water Temperatures for Natural Production of South Fork Salmon River Summer Chinook

Zones of thermal tolerance adjusted for the life cycle of South Fork Salmon River summer chinook salmon then superimposed over the annual temperature regime of the LMCR indicate that average maximum and minimum water temperatures of the LMCR fall well within temperatures tolerated by chinook salmon and the 600 tu required for fry emergence would be available at Peck from November 8-16 and at Spalding from November 5-12 (Figures 7 and 8)(Appendix A, Tables A1-4).

Notably, absolute water temperatures at Peck and Spalding exceed the upper incipient lethal temperature of adult chinook salmon (Coutant 1970) during July and August (Figure 7 and 8). Early egg incubation may be threatened by absolute maximum temperatures between September and October. Absolute minimum water temperatures fall below the lower incipient lethal temperatures of incubating chinook eggs (Combs 1965) from November through February (Figure 7 and 8).

We examined USGS data from Peck gaging station and found that during summer chinook staging, spawning and egg incubation periods lethal temperatures occurred infrequently and rarely for 24 consecutive hours (Appendix B, Tables B1-5).

Absolute minimum temperatures were identified in Figure 7 during December, January, and February that may influence emerging fry survival (< 0.8 °C). December monthly minimum temperatures below 0.8 °C occurred in 1972, 1975, and 1977, but never for an entire 24-h period (Appendix B, Table B6). During January monthly minimum temperatures were recorded below 0.8 °C seven of fourteen years, but remained this low for 24-h only twice (Appendix B, Table. B7). February temperature were poor for rearing six of the fifteen years water temperature data since Dworshak Dam operation. The longest time that water temperature remained below 0.0 °C was 3 consecutive days in 1979 (Appendix B, Table B8).

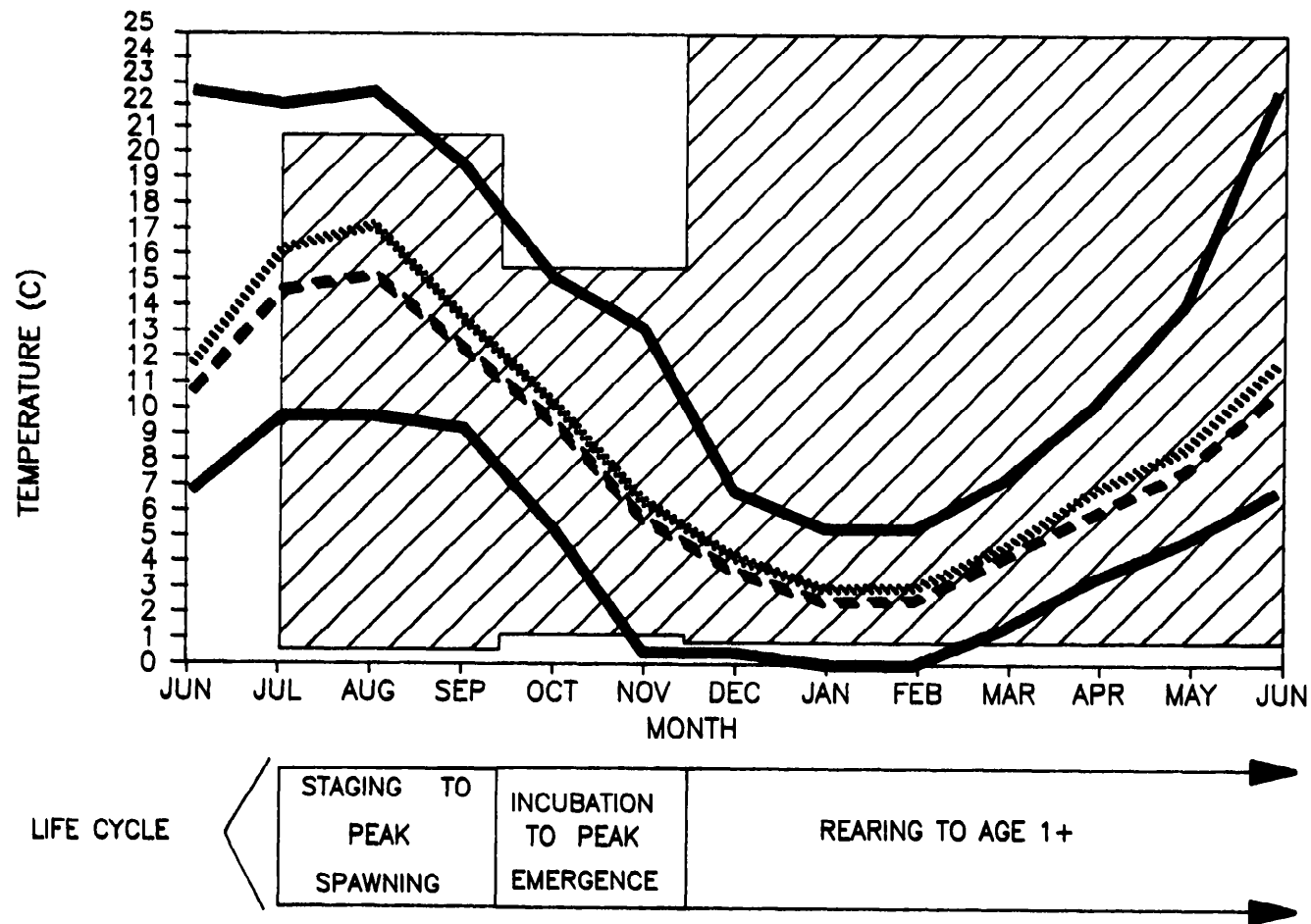


Figure 7. Zone of thermal tolerance for summer chinook salmon (hatched) at various life stages superimposed over absolute maximum (thick solid), absolute minimum (thin solid), average monthly maximum (dotted), and average monthly minimum (dashed) temperatures determined using United States Geological Survey data from Peck gaging station, Clearwater River, Id October 1972 – September 1987.

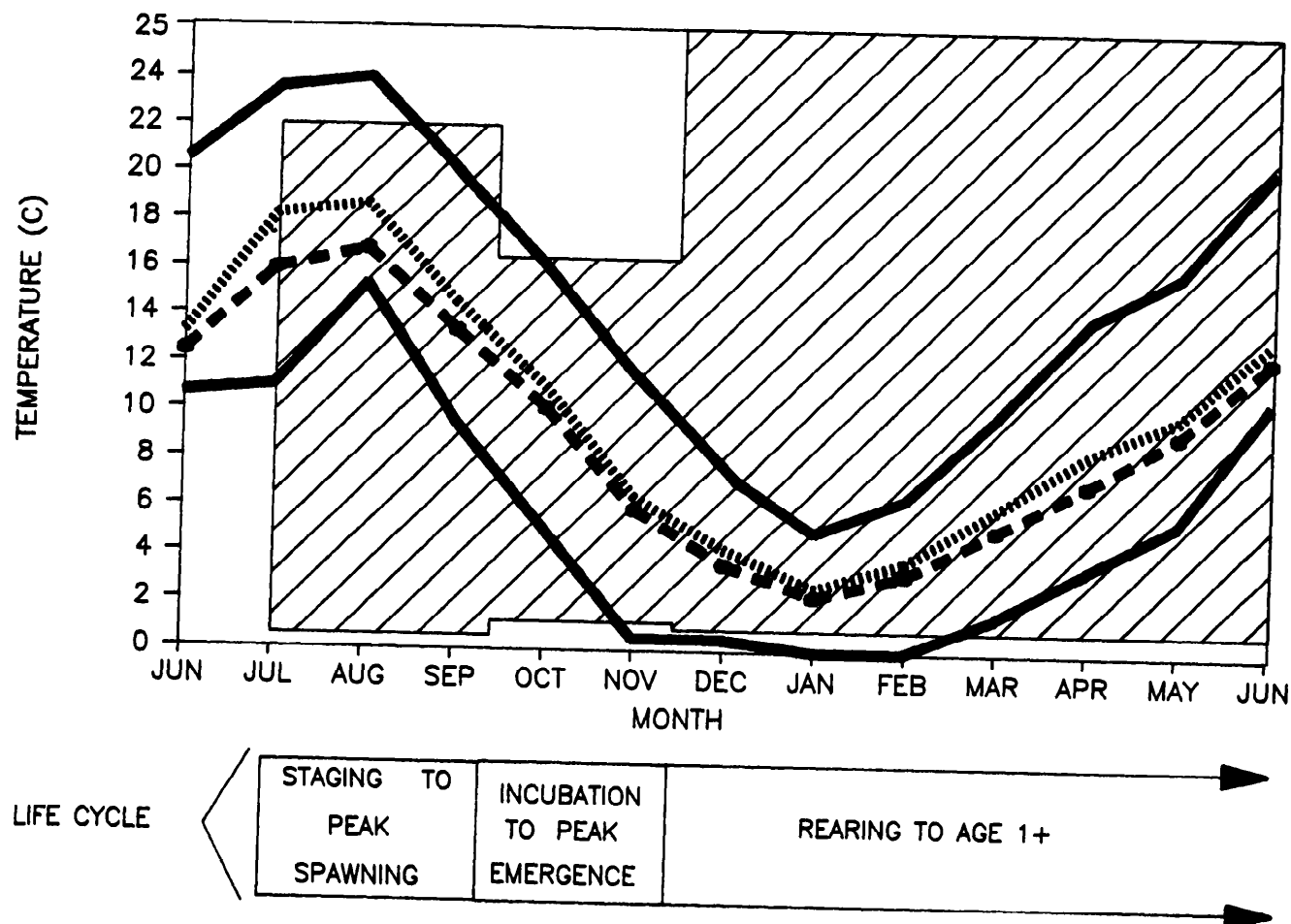


Figure 8. Zone of thermal tolerance for summer chinook salmon (▨) at various life stages superimposed over absolute maximum (—), absolute minimum (—), average monthly maximum (.....), and average monthly minimum (---) temperatures determined using United States Geological Survey gaging station data from Spalding, Clearwater River, Idaho October 1972 – September 1986.

We scrutinized USGS water temperature data from Spalding and found that temperatures lethal to chinook salmon adults and eggs occurred infrequently and rarely for 24 consecutive hours (Appendix B, Tables 59-13).

December, January, and February monthly minimum temperatures at Spalding may affect overwinter juvenile summer chinook survival. December minimum temperature and corresponding maximum daily temperature remained below 0.8 °C in 1972, but not for 24-h (Appendix B, Table B14). During January six of fourteen years had suboptimal monthly minimum temperatures. In 1979 these temperatures persisted for 11 consecutive days (Appendix B, Table B15). February monthly minimum temperature fell below 0.8 °C three years from 1973-1986, but never for 24 consecutive hours (Appendix B, Table B16).

Relevance of Water Temperature Data to Natural Summer Chinook Salmon Spawning, Incubation, and Early Rearing

Postponed upstream migration and delayed spawning and potential mortality are the most apparent consequences of excessively high water temperatures concurrent to chinook spawning runs. Upstream migration can be halted by water temperatures greater than 20.0 °C (Stabler et al. 1976, Reiser and Bjornn 1979). Chinook salmon have been known to spawn at temperatures as high as 24.9 °C, but prefer temperatures ranging from 7.2-12.7 °C (Piper et al. 1982).

Our analysis indicates that LMCR temperatures at Peck and Spalding could delay or prohibit staging in early August. Spawning may be delayed proportionately to staging or commence upon fish arrival. Temperatures during late August/early September when summer chinook would presumably be spawning, offer no direct threat to adult fish or spawning success.

Unsuitable water temperature during early incubation could directly affect egg survival. A study cited by Combs and Burrows (1957) documented significant chinook egg mortality attributable to an early incubation temperature of 15.5 °C. Conversely, Olson and Foster (1965) referred to a report of successful Willamette River chinook incubation starting at water temperatures as high as 18.0 °C.

Applying this information to LMCR maximum and minimum temperatures available for incubation at Peck and Spalding is complicated, but in general it appears that in some years absolute maximum September temperatures (16.5-19.0 °C) could reduce egg survival through early incubation. Critical

November minimum temperatures (Figure 7) occurred infrequently and were of short duration and probably would not affect incubation through emergence.

Little written information was found to document the behavior of early winter emerging chinook salmon. However, studies done on young chinook approaching age-1 may provide a better understanding of the effects of dropping water temperatures on chinook fry behavior. Young chinook rearing in small tributaries of Idaho during summer often migrate downstream to overwinter in larger rivers (Chapman and Bjornn 1969). Miller (1969) examined this behavior in artificial channels and found that of the variables he tested water temperatures evoked the strongest migratory response. This response was most notable as temperatures decreased to 4.4 °C, then it ceased at 1.7 °C. When temperature decreases below 5.5-4.4 °C chinook salmon fry often swim into the gravel or under large rocks to overwinter (Chapman and Bjornn 1969).

This information can be used to assess survival of summer chinook salmon should they emerge in the LMCR in mid-November as estimated. November average temperatures of 5.9-6.6 °C (Appendix A, Tables A1-4) are suitable for emergence and early rearing and minimum November temperatures detrimental to young chinook salmon occur infrequently and for short time periods. As average temperatures decline to 4.4-3.8 °C in December, fry might start downriver migration accompanied by winter-hiding in the substrate. Existence of winter cover in downriver reaches of the LMCR would be essential to fry survival through critical January and February minimum temperatures.

Suitability of LMCR Water Temperature for Natural Production of Snake River Fall Chinook Salmon

Zones of thermal tolerance adjusted for the life cycle of Snake River fall chinook salmon then superimposed over the annual temperature regime of the LMCR indicate that average maximum and minimum water temperatures fall well within temperatures tolerated by these fish (Figures 9 and 10) and the 1,000 tu required for fry emergence would be available from May 25 to June 12 at Peck and from May 17 to May 30 at Spalding (Appendix A, Tables A5-8).

Notably, absolute maximum temperatures at Peck and Spalding exceeded the upper incipient lethal temperature of adult chinook salmon during August (Figures 9 and 10). Temperatures have periodically occurred that are suboptimal for early incubation of chinook eggs during November, December, January and February (Figure 9 and 10). Absolute maximum temperatures in June have been above the temperature tolerated by incubating chinook eggs (Figure 9 and 10).

Scrutinization of USGS data from Peck indicates that adult fall chinook staging may be affected by late summer maximum temperatures in excess of 22.0 °C. August maximum temperatures attained 22 °C twice in fourteen years and temperatures dropped below 21.0 °C during both days (Appendix B, Table B2). Monthly August maximum temperature around 20 °C are common (Appendix B, Table B2).

November, December, January, and February were identified as having absolute minimum water temperatures (1.7 °C) that could reduce egg survival through incubation at Peck. November temperatures were near 0.0 °C for one 24-h period in 1977 (Appendix B, Table B5). During December the minimum monthly temperature was below 1.7 °C eight of fourteen years of record. And 24-h water temperature stayed below 1.7 °C for 2-d in 1972, and 1-d in 1985 (Appendix B, Table B6). January minimum temperatures fell below 1.7 °C 12 of 14 years, remaining suboptimal for 17-d total (Appendix B, Table B7). The longest that water temperature stayed below 1.7 °C was two consecutive 24-h periods (Appendix B, Table B7). Ten of fourteen February monthly minimum temperatures were below 1.7 °C (Appendix B, Table B8). During 1979, the water temperature remained at 0.0 °C for four consecutive days (Appendix B, Table B8).

The months of May and June were identified as having absolute maximum temperatures capable of killing eggs (Figure 9). However, there were no temperatures recorded by USGS during May (Appendix B, Table B17) in excess of 16.1 °C indicating that June temperatures were responsible for the pattern seen in Figure 9. During four of fourteen years USGS recorded June temperatures greater than 16.1 °C (Appendix B, Table B18). All June maximum temperatures, including the absolute maximum of 23 °C recorded in 1987, fall in the last week of June (Appendix A, Table A5).

Examination of USGS data indicates that adult fall chinook staging may be affected at Spalding since two of fourteen August maximum temperatures have been recorded in excess of 22.0 °C (Appendix B, Table B10). The temperatures dropped during the day in both cases. August temperatures in excess of 20.0 °C are common near Spalding (Appendix B, Table B10).

November, December, January, and February were identified as having absolute minimum water temperatures that could reduce survival through incubation (cl.7 °C). Three of fourteen November minimum water temperatures were below 1.7 °C since 1972, but the temperatures remained this low for 24-h only once (Appendix B, Table B13). December daily minimum temperatures remained below 1.7 °C for 2-d in 1972, 3-d in 1976 and 3-d in 1981 (Appendix B, Table B14). January minimum remained below 1.7 °C for 8, 11, 2, and 2 consecutive days in 1973, 1979, 1982, 1984, and 1986, respectively. In 1973, 1977, 1979, and 1980 daily minimum temperature hovered near 0.0 °C (Appendix B, Table B15). February minimum temperatures have been suboptimal for incubation three of fourteen years temperature data has been available. The least favorable conditions occurred in 1981 while water temperature was 1.5 °C for four consecutive days (Appendix B, Table B16).

May and June absolute maximum temperatures at Spalding were identified as having the potential of reducing egg survival during late incubation (Figure 10). There were no May temperatures in excess of 16.1 °C (Appendix B, Table B19) indicating June temperatures were responsible for the pattern seen in Figure 10. Seven of fourteen June maximum temperatures attained 16.1 °C (Appendix B, Table B20). However, these temperatures occurred in the end of June after estimated fry emergence (Appendix A, Tables A7 and 8).

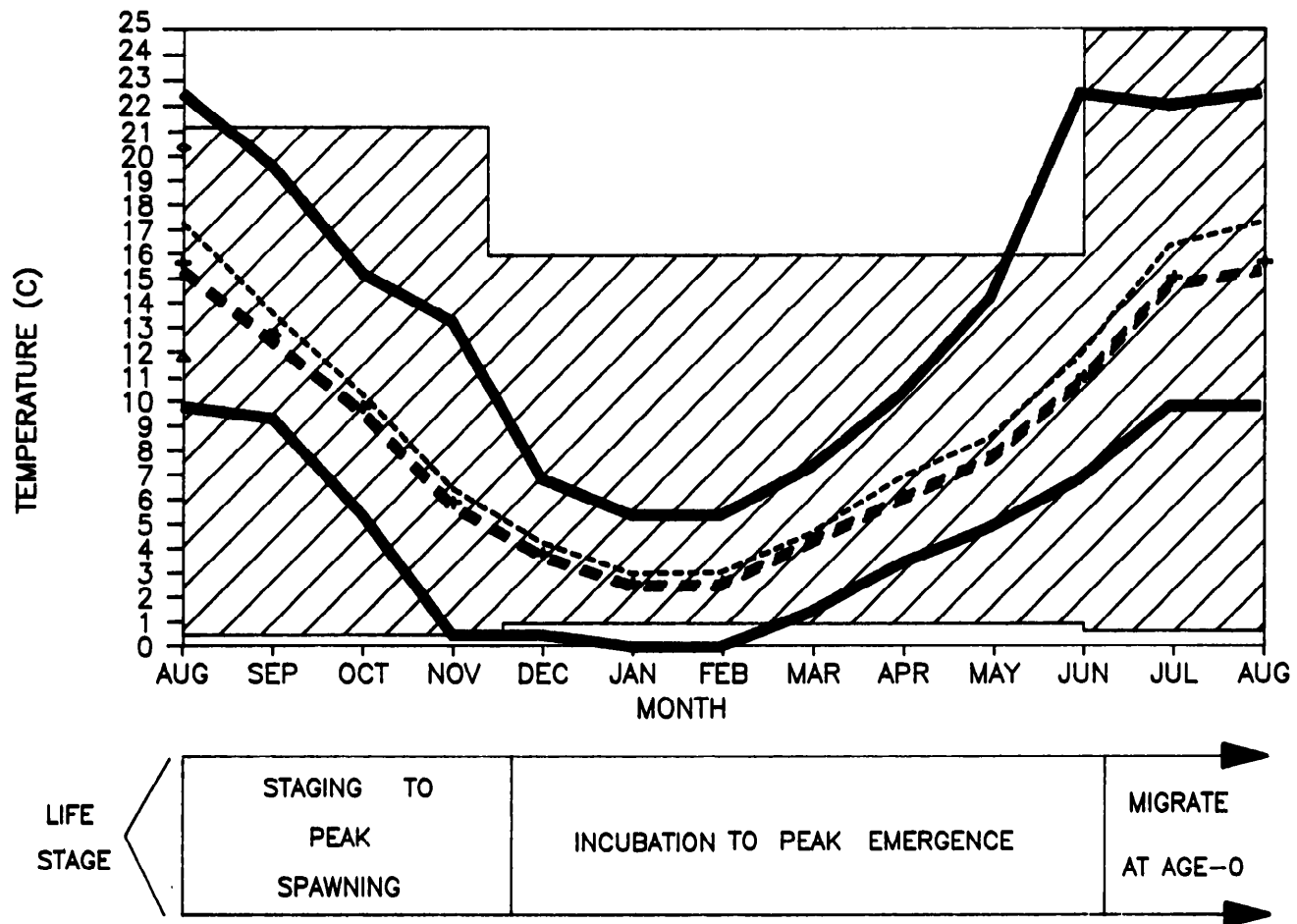


Figure 9. Zone of thermal tolerance for Fall chinook salmon (///) at various life stages superimposed over absolute maximum (—), absolute minimum (—), average monthly maximum (-----), and average monthly minimum (— · —) temperatures determined using United States Geological Survey data from Peck gaging station, Clearwater River, ID October 1972 – September 1987.

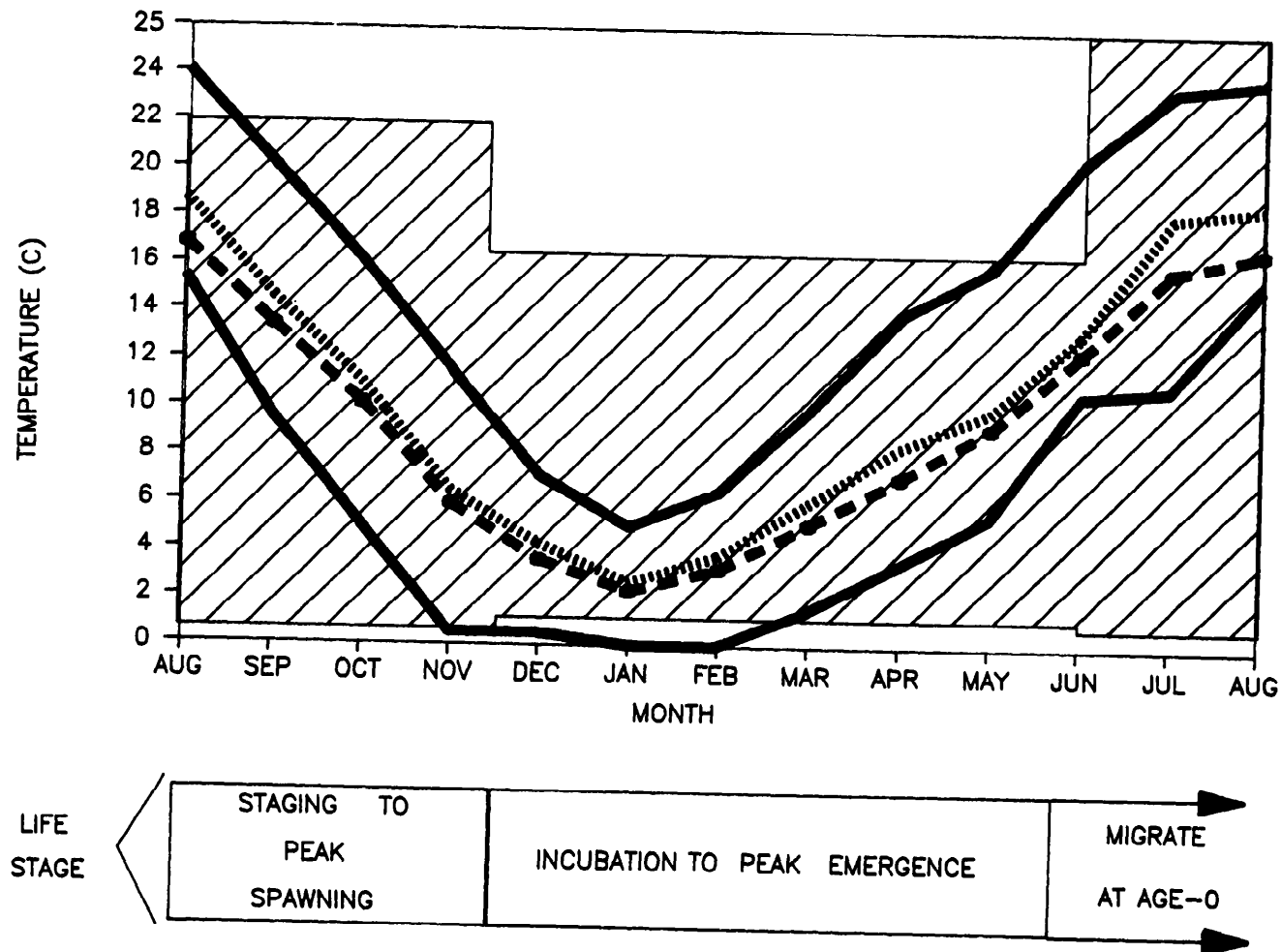


Figure 10. Zone of thermal tolerance for Fall chinook salmon (shaded area) at various life stages superimposed over absolute maximum (solid thick line), absolute minimum (solid thin line), average monthly maximum (dashed line), and average monthly minimum (dotted line) temperatures determined using United States Geological Survey gaging station data from Spalding, Clearwater River, Id October 1972 - September 1986.

Relevance of Water Temperature Data to Natural Fall Chinook Salmon Spawning and Incubation

The high August water temperatures present since 1972 could delay fall chinook migration from the Snake River into the LMCR. The significance of a migration delay would be minor since Snake River Fall chinook could access the LMCR by September and do not spawn until late October through November (Howell et al. 1985). Temperatures during the later part of October through at least mid-November would accommodate chinook spawning. However, excessively cold water temperature during late December, January, and February could reduce incubation success.

Extended periods of cold water during incubation can threaten egg survival by causing formation of frazil, anchor, and intra-gravel ice. Studies cited by Reiser and Wesche (1979) examined the environmental requirements believed to cause underwater ice formation. Water temperatures below 0 °C were discussed as possible prerequisites to frazil ice formation. Frazil ice consists of small ice crystals floating in the water column. Aggregates of frazil ice adhere to the substrate to form anchor ice. Anchor ice can impede water flow into the substrate and kill incubating eggs (Reiser and Bjornn 1979).

Under conditions of low intra-gravel water velocity, water flowing through gravel interstices can freeze solid forming intra-gravel ice. Reiser and Wesche (1979) documented complete mortality in three brown trout (Salmo trutta) redds as a result of intra-gravel freezing.

Information concerning underwater ice formation is relevant to our research on the LMCR because extended periods of 0 °C temperatures have occurred even under the influence of Dworshak Dam effluent. However, we have not found any documentation of anchor ice forming in potential spawning areas on the LMCR since 1972. Nonetheless, cold water periods identified in this analysis could potentially reduce chinook survival to emergence in some years, but this situation is common in Pacific Northwest streams and salmon stocks seem to overcome it.

Suitability of LMCR Summer Maximum Water Temperatures for Chinook Salmon and Steelhead Trout Rearing

Post Dworshak Dam summer daily maximum water temperatures were analyzed to determine their impact on chinook salmon and steelhead trout summer rearing in the LMCR. Direct lethality and indirect effects on juvenile growth were examined.

Chinook lethality:

Absolute maximum summer water temperatures at Peck and Spalding did not exceed the upper incipient lethal temperature for pre-smolt chinook salmon given by Brett (1952) (Figures 11 and 12) from 1972-1987. However, average maximum summer water temperatures at Peck and Spalding were 2-5 °C warmer than the optimum temperatures for chinook juvenile production reported in the literature (Brett 1952) (Figures 9 and 10).

Steelhead lethality:

Absolute maximum summer water temperatures at Peck were below the 23.9 °C upper level tolerated by juvenile steelhead trout (Bell in Bjornn and Reiser unpublished manuscript) and average summer water temperatures are 2-3 °C warmer than optimum temperatures for juvenile steelhead production (Figure 13). During August absolute temperatures at Spalding exceeded the upper incipient lethal temperature of steelhead trout used in our analysis (Figure 14) 1-d in fourteen years (Appendix B, Table B10). Average summer temperatures are 2-4 °C in excess of optimum rearing temperatures (Bell in Bjornn and Reiser unpublished manuscript) (Figure 12).

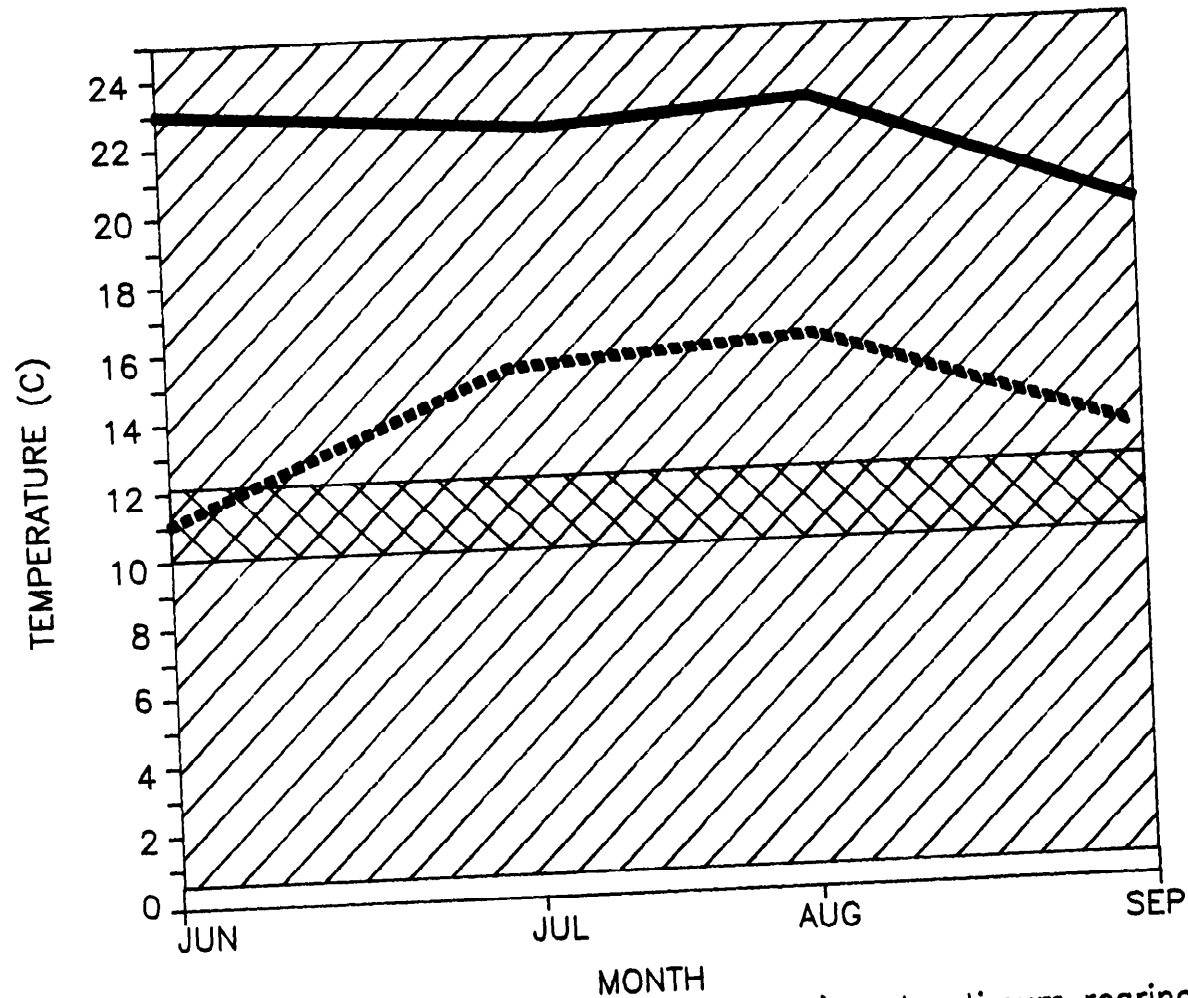


Figure 11. Zones of thermal tolerance (diagonal lines) and optimum rearing temperatures (cross-hatch) for pre-smolt chinook salmon as defined in the literature superimposed over lower mainstem Clearwater River absolute (solid line) and average (dashed line) maximum summer water temperatures recorded by USGS at Peck, Idaho 1973–1987.

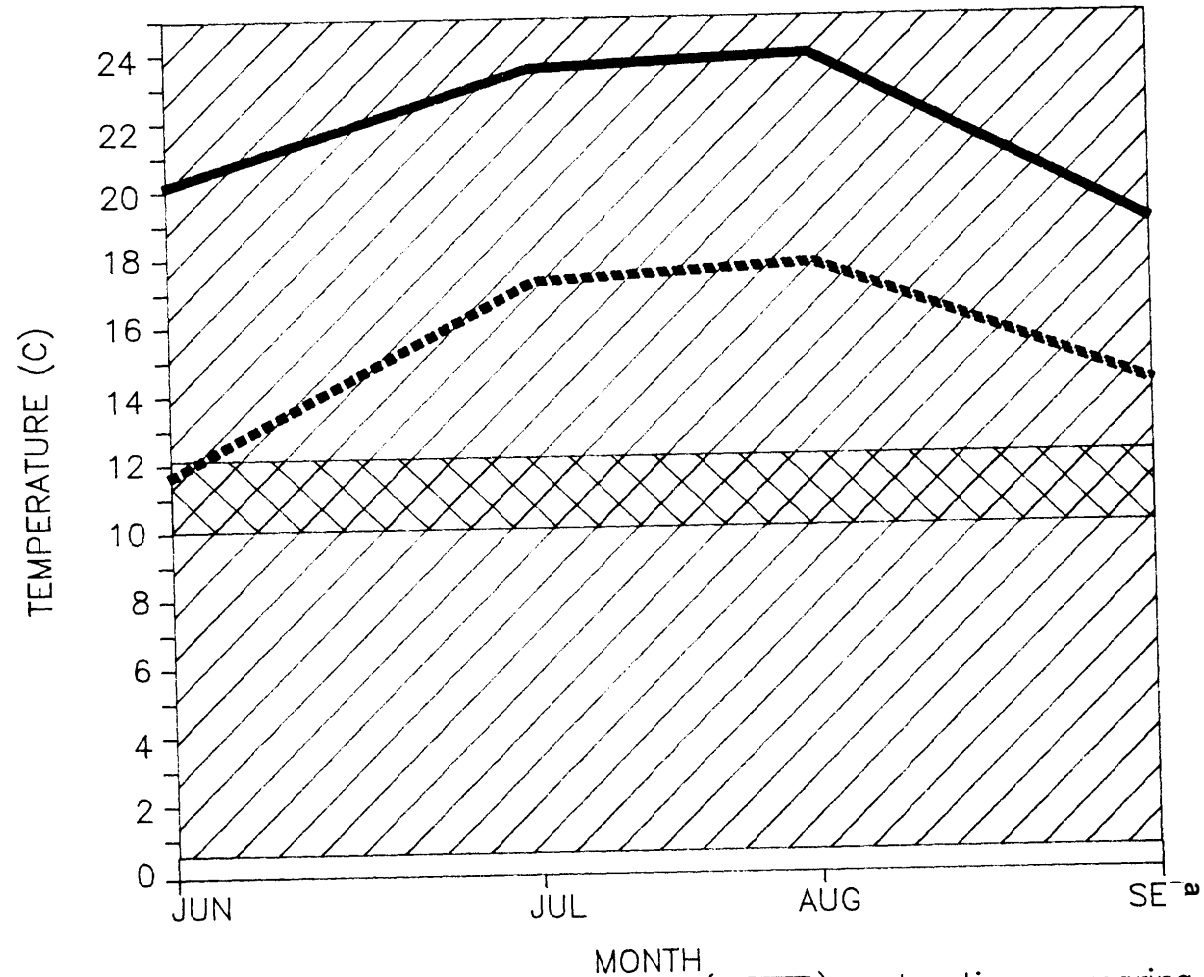


Figure 12. Zones of thermal tolerance (▨▨▨▨) and optimum rearing temperatures (▩▩▩▩) for pre-smolt chinook salmon as defined in the literature superimposed over lower mainstem Clearwater River absolute (—) and average (-----) maximum summer water temperatures recorded by USGS at Spalding, Idaho 1973–1987.

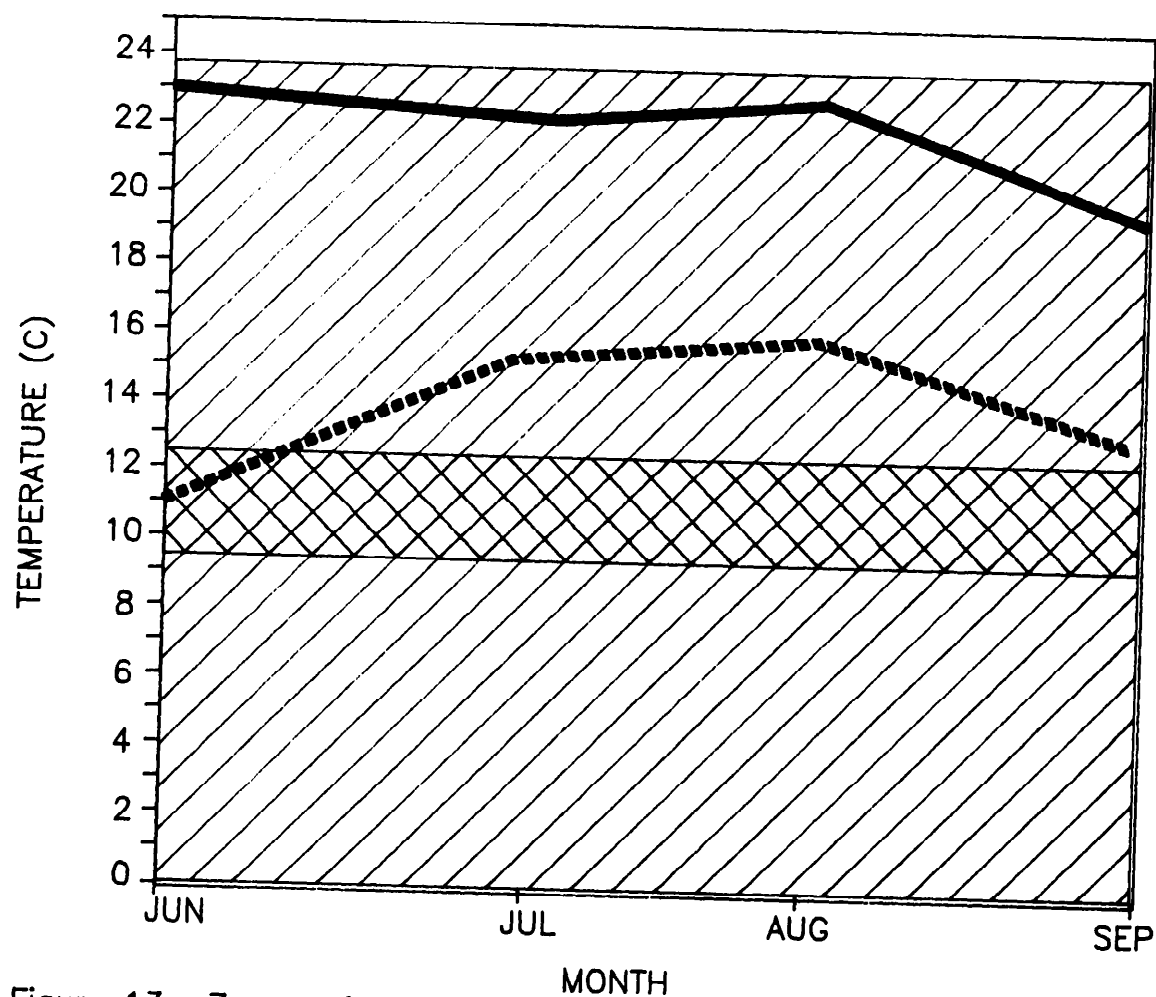


Figure 13. Zones of thermal tolerance (▨▨▨) and optimum rearing temperatures (▩▩▩) for pre-smolt steelhead trout as defined in the literature superimposed over lower mainstem Clearwater River absolute (—) and average (-----) maximum summer water temperatures recorded by USGS at Peck, Idaho 1973–1987.

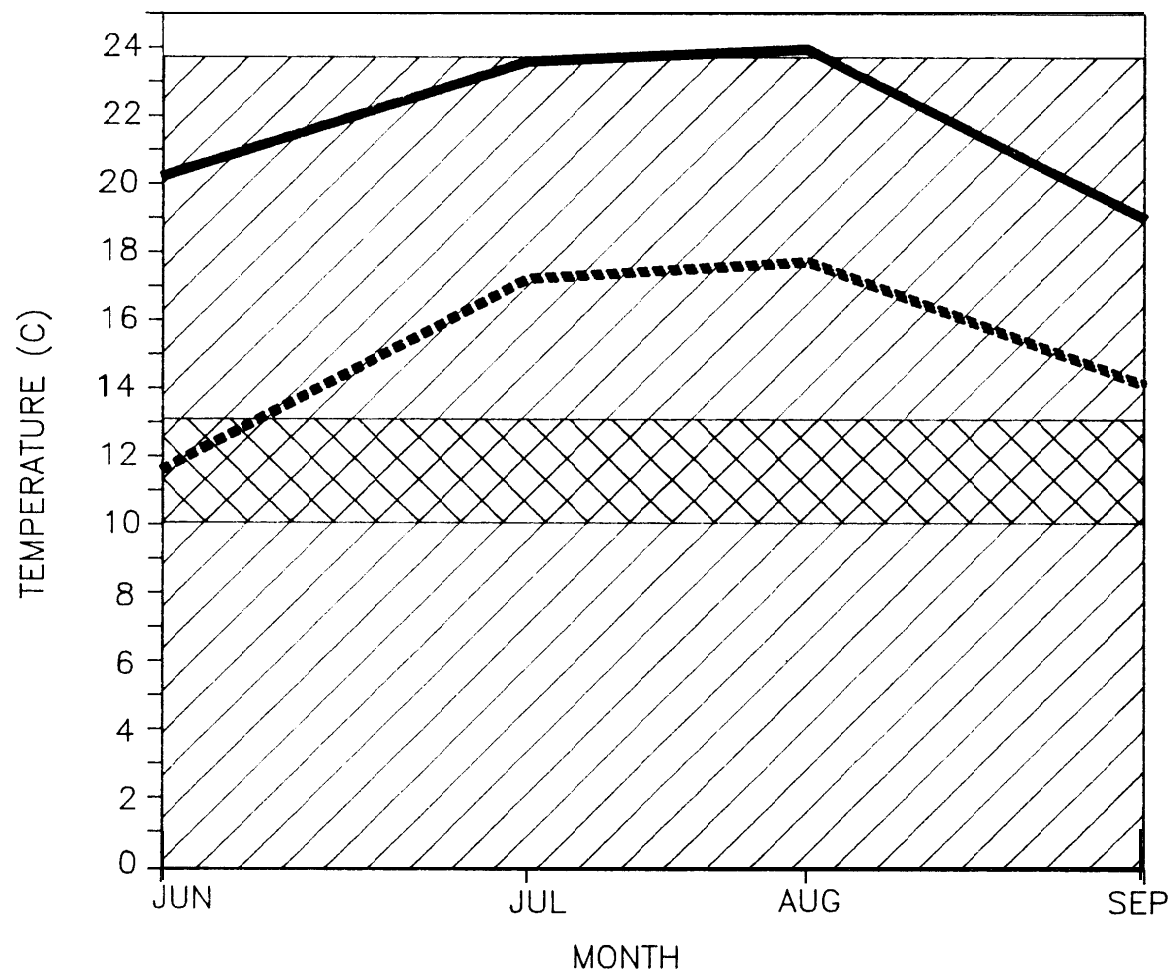


Figure 14. Zones of thermal tolerance (▨▨▨) and optimum rearing temperatures (▩▩▩) for pre-smolt steelhead trout as defined in the literature superimposed over lower mainstem Clearwater River absolute (—) and average (-----) maximum summer water temperatures recorded by USGS at Spalding, Idaho 1973–1987.

Chinook salmon and steelhead trout growth:

Average weekly water temperatures at Peck exceeded the MWAT for chinook salmon during the last week of July and the first two weeks of August (Tables 4 and 5). The MWAT calculated for steelhead trout was attained or exceeded the last two weeks of July and all of August (Tables 4 and 5).

Average weekly temperatures at Spalding exceeded the MWAT for chinook salmon the last two weeks of July and first three weeks in August (Tables 6 and 7). The MWAT for steelhead trout was attained or exceeded throughout July and August (Tables 6 and 7).

Table 4. July average weekly temperatures calculated using USGS data from Peck gaging station, Clearwater River, Idaho and Maximum Weekly Average Temperature (MWAT) not to be exceeded for optimum chinook salmon and steelhead trout growth.

Week	<u>Average weekly temperature</u>			Chinook MWAT	Steelhead MWAT
	minimum	maximum	average		
1	13.8	15.2	14.5	17.0	15.6
2	14.4	16.2	15.3	17.0	15.6
3	15.7	16.9	16.1	17.0	15.6
4	16.2	18.2	17.2	17.0	15.6

Table 5. August average weekly temperatures calculated using USGS data from Peck gaging station, Clearwater River, Idaho and Maximum Weekly Average Temperature (MWAT) not to be exceeded for optimum chinook salmon and steelhead trout growth.

Week	<u>Average weekly temperature</u>			Chinook MWAT	Steelhead MWAT
	minimum	maximum	average		
1	16.7	18.8	17.8	17.0	15.6
2	16.5	18.5	17.5	17.0	15.6
3	15.2	17.4	16.3	17.0	15.6
4	14.7	16.5	15.6	17.0	15.6

Table 6. July average weekly temperatures calculated using USGS data from Spalding gaging station, Clearwater River, and Maximum Weekly Average Temperature (MWAT) not to be exceeded for optimum chinook salmon and steelhead trout growth.

Week	<u>Average weekly temperature</u>			Chinook MWAT	Steelhead MWAT
	minimum	maximum	average		
1	14.9	16.4	15.7	17.0	15.6
2	15.2	17.5	16.4	17.0	15.6
3	16.0	18.6	17.3	17.0	15.6
4	17.1	19.7	18.4	17.0	15.6

Table 7. August average weekly temperatures calculated using USGS data from Spalding gaging station, Clear-water River, Idaho and Maximum Weekly Average Temperature (MWAT) not to be exceeded for optimum chinook salmon and steelhead trout growth.

Week	<u>Average weekly temperature</u>			Chinook MWAT	Steelhead MWAT
	minimum	maximum	average		
1	17.7	19.7	18.7	17.0	15.6
2	17.4	19.4	18.4	17.0	15.6
3	16.2	18.4	17.3	17.0	15.6
4	15.6	17.7	16.7	17.0	15.6

Relevance of LMCR Summer Water Temperatures to Anadromous Salmonid Rearing

Water temperatures are not always optimum in even the most productive salmon and steelhead trout rivers. Summer water temperatures within the Hanford Reach of the Columbia River exceed 20 °C, yet this stretch of water produces viable chinook salmon runs (Becker 1970). Kucera (personal communication) observed steelhead rearing in Clearwater River tributaries with temperatures as high as 26.0 °C. Juvenile anadromous salmonids can obviously rear successfully in suboptimum water temperatures, as long as these temperatures are within a suitable range.

The average maximum summer water temperatures at Peck and Spalding gaging stations are suitable for chinook salmon and steelhead trout rearing. Preliminary analysis shows that absolute summer water temperatures are rarely high enough to be directly lethal to rearing juveniles. Indirect effects of suboptimum rearing temperatures such as increased disease susceptibility, increased susceptibility to predation, and decreased growth rates may influence rearing juvenile survival. Disease and predation effects could not be quantified, however we did approximate growth effects. Growth effects might occur from late July through August in the LMCR. Brett in Armour (unpublished manuscript) documented sublethal stress in spring chinook salmon reared at 18.5 °C. These fish grew 20% less than fish reared in an optimum temperature near 14.8 °C. Perhaps, less than optimum chinook salmon and steelhead growth may be expected

in the LMCR if food is not plentiful enough to meet increased metabolic needs associated with warmer water temperatures.

Successful Outmigration from the Clearwater into the Upper Snake River

Critical fish size at the time of the April 15 - June 15 Water Budget was identified as the most important factor influencing summer chinook smoltification.

Successful fall chinook outmigration from the Clearwater into the Snake River and past Lower Granite Dam was evaluated on the basis of critical fish size required for smoltification relative to the timing of the April 15 - June 15 Water Budget and Clearwater River discharge at the time of emergence.

Growth to critical smolt size:

Growth estimate calculations for summer chinook salmon indicate that juveniles would approach smolt size (102-127 mm) by the end of September through April and by the end of August through September at Peck and Spalding respectively (Tables 8 and 9).

Growth estimate calculations for fall chinook salmon indicate that juveniles would approach smolt size (70-80 mm) by the end of August through September at both Peck and Spalding (Tables 10 and 11).

Table 8. Use of monthly temperature data from Peck to estimate juvenile South Fork Salmon River summer chinook size based on the fact that summer chinook reared at McCall Hatchery required 0.82 MTU's for 1 millimeter growth in 3.0 - 12.6 °C water.

Month	Average monthly temperature	Growth (mm)	End of month size (mm)
November	6.3	7.7	23.4*
December	4.1	—	23.4
January	2.8	—	23.4
February	2.9	—	23.4
March	4.7	—	23.4
April	6.6	8.0	31.4
May	8.3	10.1	41.6
June	11.6	14.1	55.7
July	15.9	19.4	75.1
August	16.6	20.2	95.4
September	13.3	16.2	111.6
October	10.1	12.3	123.9
November	6.3	7.7	131.6
December	4.1	—	131.6
January	2.8	—	131.6
February	2.9	—	131.6
March	4.6	—	131.6
April	6.6	8.0	139.6

*Based on swim-up fry size of 20 mm

Table 9. Use of monthly temperature data from spalding to estimate juvenile South Fork Salmon River summer chinook size based on the fact that summer chinook reared at McCall Hatchery required 0.82 MTU's for 1 millimeter growth in 3.0 - 12.6 °C water.

Month	Average monthly temperature	Growth (mm)	End of month size (mm)
November	6.2	7.6	23.4*
December	3.8	—	23.4
January	2.5	—	23.4
February	3.5	—	23.4
March	5.6	6.8	30.2
April	7.8	9.5	39.7
May	9.6	11.7	51.4
June	12.8	15.6	67.1
July	17.1	20.9	87.9
August	17.6	21.6	109.5
September	14.0	17.1	126.6
October	10.6	12.9	139.5
November	6.2	7.6	147.1
December	4.0	—	147.1
January	2.5	—	147.1
February	3.7	—	147.1
March	5.6	6.8	153.9
April	7.8	9.5	163.4

*Based on swim-up fry size of 20 mm

Table 10. Use of monthly temperature data from Peck to estimate juvenile Snake River fall chinook size based on the fact that summer chinook reared at McCall Hatchery required 0.82 MTU's for 1 millimeter growth in 3.0 - 12.6 °C water.

Month	Average monthly temperature	Growth (mm)	End of month size (mm)
June	11.6	14.1	34.1
July	15.9	19.4	53.5
August	16.6	20.2	73.7
September	13.3	16.2	89.9

*Based on swim-up fry size of 20 mm

Table 11. Use of monthly temperature data from Spalding to estimate juvenile Snake River fall chinook size based on the fact that summer chinook reared at McCall Hatchery required 0.82 MTU's for 1 millimeter growth in 3.0 - 12.6 °C water.

Month	Average monthly temperature	Growth (mm)	End of month size (mm)
June	12.8	15.6	35.6
July	17.1	20.9	56.5
August	17.7	21.6	78.1
September	14.0	17.1	95.2

*Based on swim-up fry size of 20 mm

Current Water Budget timing and chinook salmon passage:

Based on the current Water Budget chinook salmon smolt passage during 1986-87 has occurred at Lower Granite Dam from approximately early April through the end of June, peaking about the first week of May (DeHart and Karr 1987) (Figure 15).

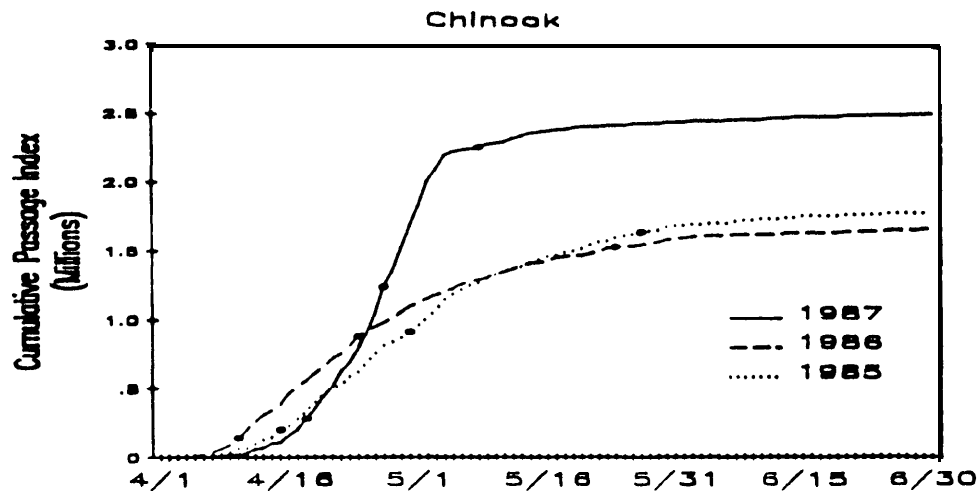


Figure 15. Cumulative passage indices at Lower Granite Dam 1985, 1986, 1987 (Dehart and Karr 1987).

Clearwater River Discharge at the time of fall chinook emergence

Fall chinook salmon would probably emerge from the gravel based on temperature, concurrent to Clearwater River peak annual discharge at both Peck and Spalding (Figures 16 and 17).

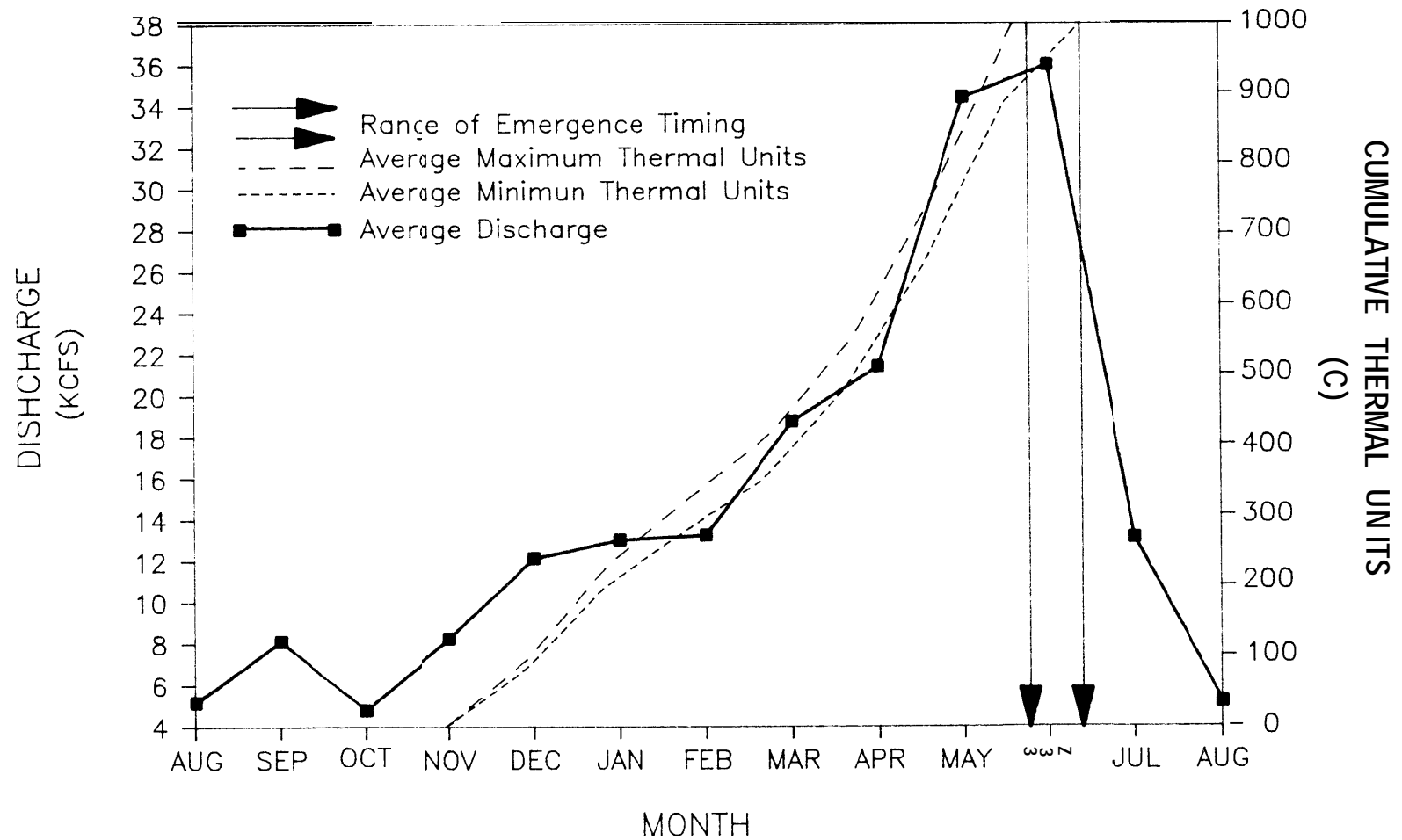


Figure 16 Estimated time of emergence for Snake River fall chinook salmon based on average daily temperature at Peck gaging station (1972–1987) and Clearwater River discharge at Peck gaging station (1973 – 1987).

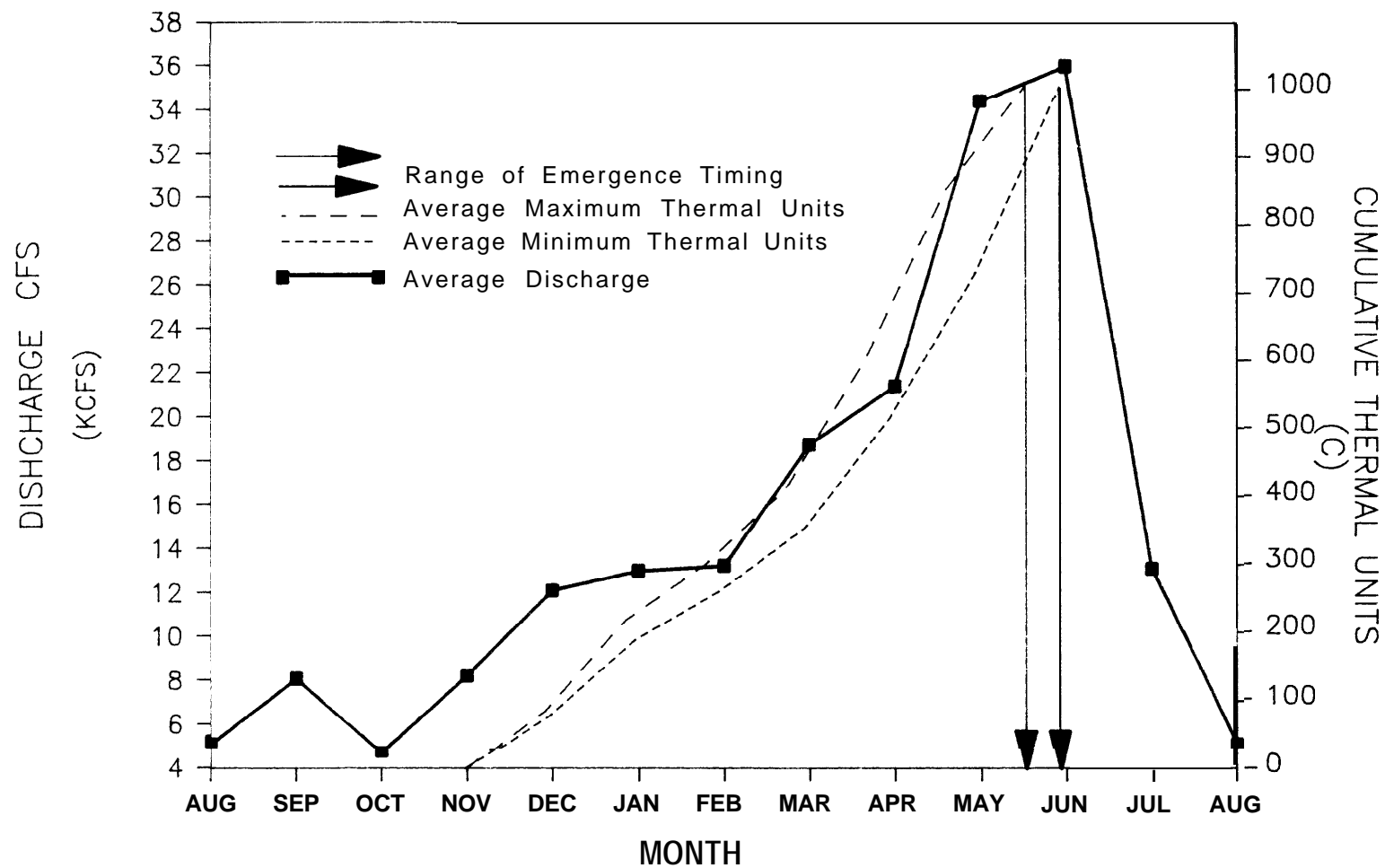


Figure 17. Estimated time of emergence for Snake River fall chinook salmon based on average daily temperatures at Spalding gaging station (1972 -1986) and Clearwater River discharge at Spalding gaging station 1972 - 1986.

Relevance of Estimated Smolt Size and the Water Budget to Successful Outmigration of Summer and Fall Chinook Salmon from the LMCR

Summer chinook salmon:

An important fact to consider when assessing the chances of successful summer chinook salmon outmigration past Lower Granite Dam, is that growth rates were probably overestimated in this analysis. Growth rate estimates were based on optimum temperatures and feeding conditions at McCall Hatchery, but LMCR temperatures during July and August (Tables 4-7) and food availability in the river, are probably less than optimum. We contend that early life history information for naturally produced summer chinook salmon fry in the LMCR is needed to estimate smoltification timing in relation to Water Budget implementation.

Fall chinook salmon:

We were unable to conclusively document whether age-0 fall chinook salmon begin active migration downriver immediately after emergence or if they rear in the vicinity of emergence until they attain critical smolt size. If age-0 fall chinook begin downstream migration immediately after leaving the gravel, peak Clearwater River discharge would accommodate this movement and successful outmigration past Lower Granite Dam would depend on the ability of the small fish to survive spilling, turbine passage, and smolt trapping. On the other hand, if fall chinook do not begin outmigration until they smolt, our preliminary analysis indicates that the mid-May to June emergence of fall chinook salmon may cause smoltification problems related to fish size. Newly emerged fall chinook salmon (approximately 20 mm) may not attain the critical size (approximately 70-80 mm) for smoltification until late summer or early fall. smolts migrating through the Columbia River system in the fall without the aid of the Water Budget would face low river velocities and warm water temperatures. Consequently, fall migrating smolts would experience increased predation and disease susceptibility, and might revert to parr before reaching the Columbia River estuary; a common problem faced by most Columbia River anadromous fish.

Potential Impacts of LMCR Flows on Anadromous Salmonid Production

Pre- and Post Impoundment Discharge

Prior to Dworshak Dam operation (1911-13 and 1926-1973) Mainstem discharge peaked at about 50,000 CFS in May receding to about 4,000 CFS in September (Figure 18). Annual maximum average discharge of 35,000 CFS now occurs in June and a minimum discharge of approximately 4,800 CFS occurs in October (Figure 19).

Regulated and Unregulated Flows

Dworshak Dam stores North Fork Clearwater River spring run-off and redistributes it throughout historically low flow periods. Consequently, post-project Lower Mainstem flows exceed pre-project flows for almost 75% of the year (Brusven and Trihey 1978).

Average daily dam discharge is released to approximate natural unregulated mainstem discharge (Figure 19). However, some deviations are present. Lower mainstem Clearwater River discharge at Peck and Spalding during September, mid-November through mid-December, and a few isolated days throughout the year, is noticeably different than unregulated flow at Orofino. These periods of increased flows are preplanned effects of Dworshak Dam flood control. Seven hundred thousand acre feet of storage space is created during September and mid-November through mid-December, through reservoir pool elevation regulation (U.S. Army Corps of Engineers 1986). Additional reservoir regulation is done to provide for unforeseen power or flood control after January 1 (U.S. Army Corps of Engineers 1986).

Discharge Fluctuation During 24-h Time Periods

Dworshak Dam discharge fluctuation during 24-h time periods (12 a.m. - 12 p.m.) occur on most days of a given month (Appendix C, Figures C1-12). The magnitude of these fluctuations is governed by flood control, power production, fish and wildlife needs, and recreation. Steelhead fisherman are accommodated during the month of October through November 15 (Appendix C, Figures C1 and 2) by avoiding discharges that exceed 40% of the previous seven day average release (U.S. Army Corps of Engineers 1986). Similar considerations are given during February 15 to April 15 (Appendix C, Figures C5-7) for spring steelhead runs and from mid-June to mid-July (Appendix C, Figures C9 and 10) for Bass spawning (U.S. Army Corps of Engineers 1986).

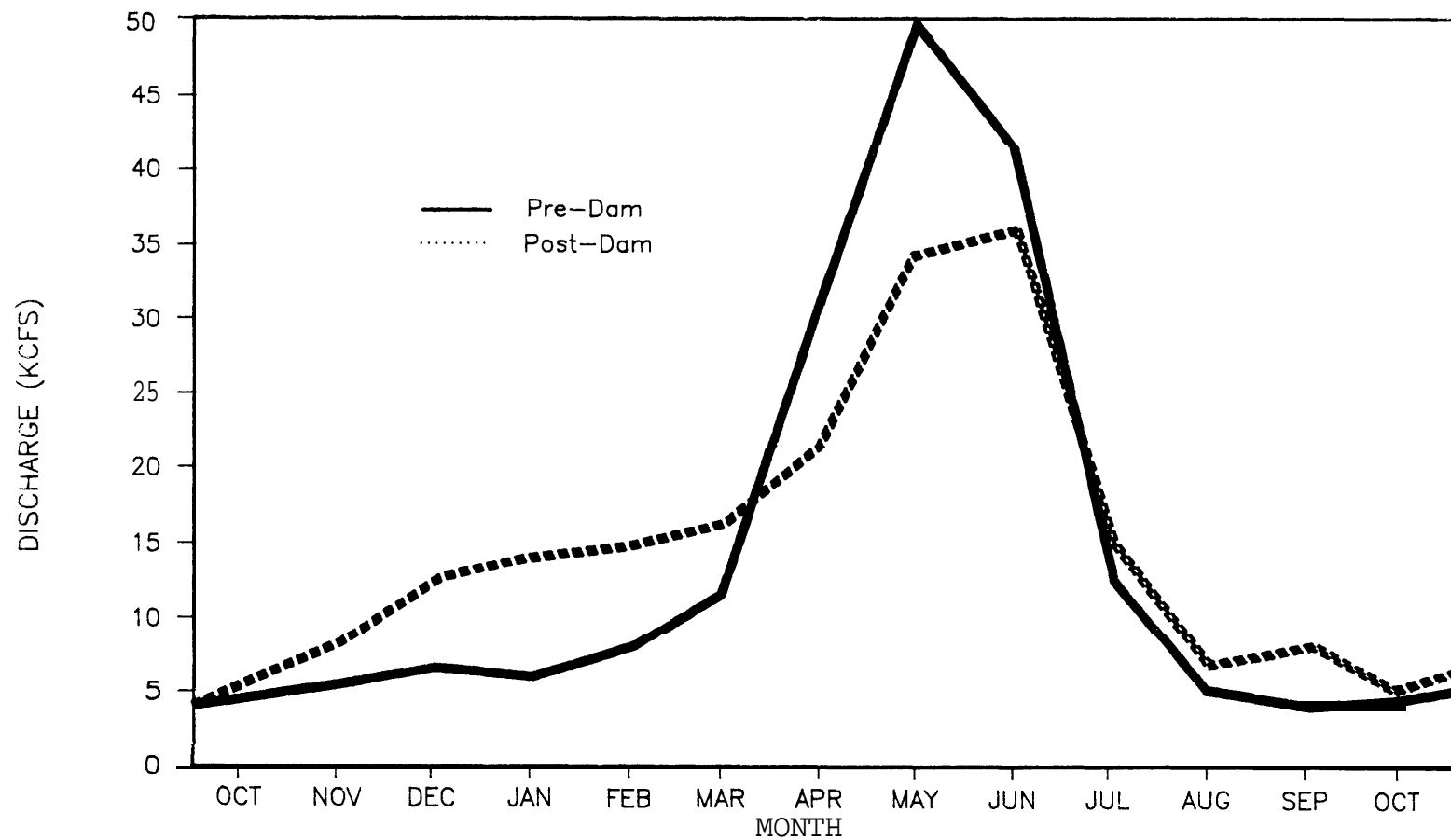


Figure 18. Comparison of mean monthly streamflows prior to Dworshak Dam (water year 1911-13, 1926-73) and post-dam (water years 1974-87) at the USGS Spalding gaging station on the lower mainstem Clearwater River.

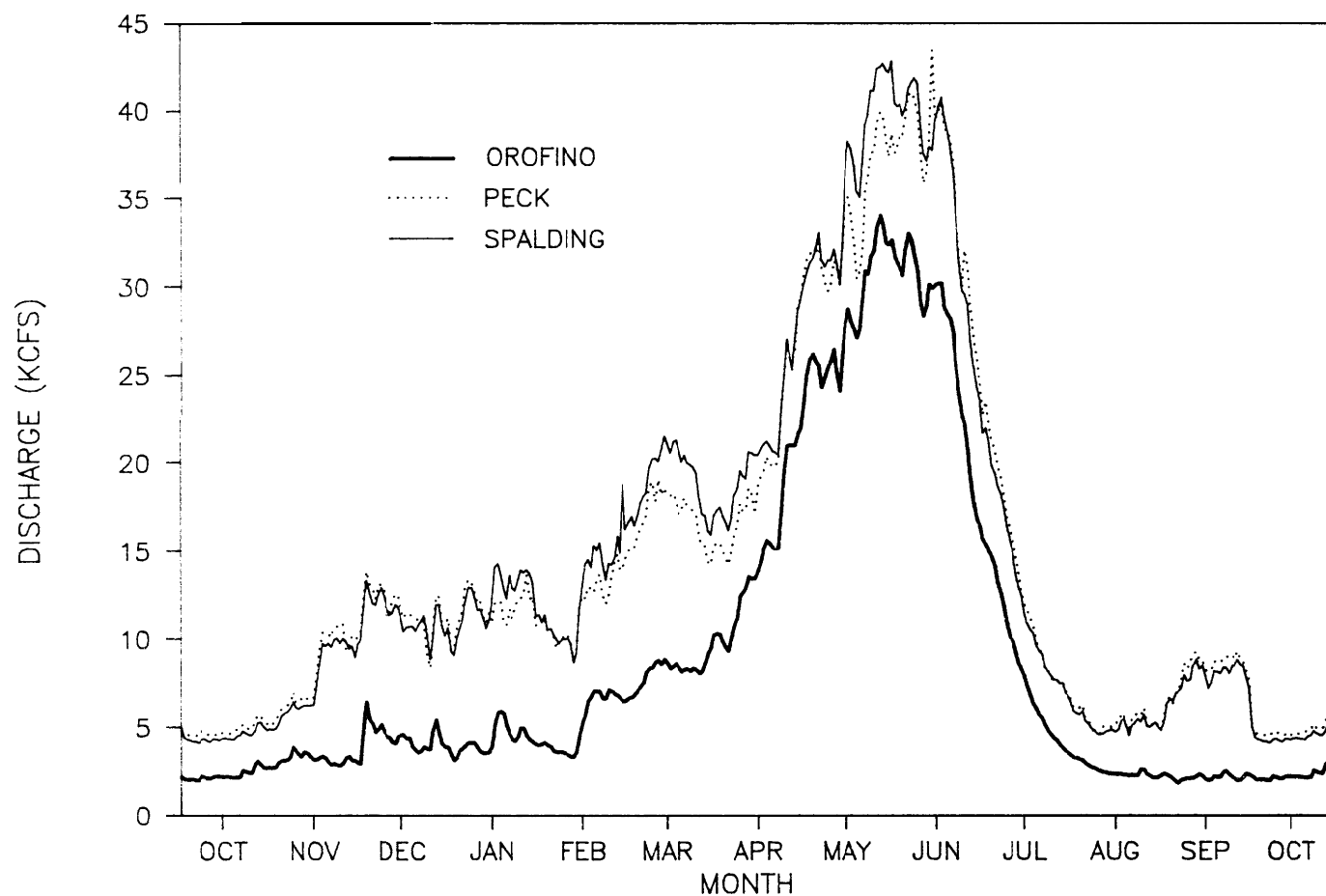


Figure 19. Average annual hydrograph for the Clearwater River at Orofino, Peck, and Spalding constructed using USGS gaging station data from October 1973 – September 1987.

Conversely, December, late April, early May, and mid to late September North Fork flows can vary as much as 6 KCFS in one day (Appendix C Figures C3, C7, C8, and C12).

Relevance of Annual and Daily Flow Fluctuations to Anadromous Fish Production in the LMCR

Riverflow fluctuation from hydropower production can affect river productivity, hydraulics, sediment and organic material deposition, water quality and temperature (Cushman 1985). Changes in these environmental components can affect salmonid spawning, incubation, and rearing habitat.

An author quoted by Bjornn and Reiser (unpublished manuscript) speculated that the quantity of spawning habitat increases with flow until water velocity becomes prohibitive. On the other hand, an abrupt decrease in flow during spawning can force salmon off of a developing redd. Chapman et al. (1986) concluded that daily 8-h minimum flows over Vernita bar did not stop fall chinook salmon from completing redds during the subsequent 16-h flow increase. Apparently, spawning salmon can dig redds if daily maximum flows do not create unsuitable velocities and daily minimum flows are exceeded long enough to provide salmon access to the gravel.

Dewatering of post spawn redds was once believed to cause complete mortality in incubating salmonid eggs and pre-emergent fry (Reiser and White 1983). Contrastingly, Reiser and White (1981 and 1983) dewatered spring chinook salmon and steelhead trout redds 1-5 weeks and found that the eggs and fry of both species developed normally if sediment moisture content stayed above 4% by sediment weight and redd temperatures remained nonlethal. Decker-Hess and Clancy (1984) also found that kokanee salmon egg fry survival in dewatered redds to the eyed stage was temperature and redd moisture content related. These Biologists reported reduced embryonic survival from 87% before dewatering to 24% after dewatering concurrent to -10°C air temperature. Survival in one dewatered redd study area was 99%. Decker-Hess and Clancy speculated that ground water wetting during dewatered periods influenced survival from redds in this study area.

The duration and magnitude of temperature and moisture content change in a dewatered redd may also influence egg and pre-emergent fry survival. Neitzel and Becker (1985) tested four intragravel development phases of chinook salmon for tolerance of heat and cold shock, and humidity changes. This study indicated that embryos are capable of surviving a change from 10°C to 26.5°C for at least 2-h. All

developmental phases tested were tolerant of coldshock if freezing did not occur. Neitzel and Becker (1985) also found that chinook fry mortality to emergence increased significantly as relative humidity decreased from 100° to 50 in a dewatered redd.

Life stage, oxygen concentration and apparent water velocity (flow by volume per unit time through a given area of gravel) may also influence egg and alevin survival in dewatered redds. Becker et al. (1982) tested four developmental phases of chinook salmon to daily dewaterings from 12 to 16-h and found egg phases more tolerant than alevins. Alderice et al. (1958) found that during early incubation Pacific salmon eggs require at least 1 p.p.m. of dissolved oxygen and 7 p.p.m. as hatching approaches. Research has shown that apparent water velocity and dissolved oxygen interact. Coble (1961) theorized that apparent velocity functioned mainly to transport oxygen, while Silver et al. 1963 felt that oxygen transfer to the embryo through the chorion is also affected by water velocity.

Water level fluctuation subsequent to emergence affects fry survival by dewatering shoreline areas and stranding juveniles. Becker et al. (1981) discussed the dependence of stranding on the timing, magnitude, and duration of flow fluctuation. He proposed that less fish are stranded if dewatering occurs during daylight hours if increases and decreases are not implemented rapidly, and if decreases are short enough to prohibit stranding pool warming (or freezing). White et al. (1985) found that juvenile steelhead density shifted from areas with cover to areas with depth as flows decreased. Inter-and intra-specific interaction at higher fish densities may also influence fish survival.

Substantial research was conducted on the LMCR to assess the effects of Dworshak Dam on aquatic invertebrate production. The results of these studies are discussed under the section of the report on food availability.

The effects of post impoundment annual and daily discharge fluctuations on potential natural anadromous fish production would depend on the life stage periodicity of the fish and cross channel geometry of the river. Summer chinook salmon spawning in late August to mid-September would be offered more spawning habitat than would be available in October for incubation (Figure 19). Fall chinook salmon spawning in mid-November would probably be unable to access suitable gravel beds, but their redds would not be dewatered during incubation (Figure 19). The cross sectional river geometry of the LMCR would also influence

the spawning incubation and rearing success. Since this feature determines the transport of North Fork peaking discharge. Brusven and Trihey (1978) predicted that changes in water surface elevation would be translated in changes in wetted perimeter depending on channel Clearwater River cross sectional geometry.

Existing Information on LMCR Water Quality

General Water Quality Parameters

Water quality is a dominant habitat parameter influencing fish populations. Water quality data available for the LMCR and its major tributaries is given in Table 12.

Table 12. Water quality parameters for the lower mainstem Clearwater River at Spalding, North Fork (N.F) Clearwater river below Dworshak Dam, Bedrock Creek, Big Canyon Creek, and Jacks Creek and the allowable range of each for salmonid culturing under hatchery conditions.

Parameter	Suggested Range ^a	N.F.	Spalding ^b	Bedrock ^c	Big ^c Canyon	Jacks ^c
Dissolved Oxygen (mg/L)	>7.0	10.1-13.4	8.1-12.7	----	---m	mm--
Ph	6.5-8.0	6.3-7.5	6.2-7.6	8.1	8.5	8.2
Total Alkalinity (mg/L CaCO ₃)	10-400	11-20	15-28	----	----	----
Total Suspended Solids (mg/L)	<80	----	0.4-7.7	----	----	----
TDS (mg/L)	10-1000	31-47	----	113	128	116
Nitrate &3/L)	0-3.0	0.02-0.4	0.25-1.0	.2-.37	.12	.92
Nitrite (mg/L)	<.1	<.001-.003	.001-.008	----	----	----

a Piper et al. (1982)

b Pettit (1976, 1977) Dave Owsley (Per. Comm.)

c Kucera and Johnson (1986), Murphy (1985, 1986)

Dissolved Gas Levels

The United States Fish and Wildlife service collected dissolved gas data from 1976-1981 which documented nitrogen saturations ranging from 99.2-127.6% (96.7-120.3% total gas pressure) (Dave Owsley pers. comm.). However, data collection was sporadic, making it difficult to conclusively identify gas supersaturation periodicity and duration. In general it appears that gas supersaturation is associated with spilling and is most common from February through June.

Adult Dworshak Hatchery summer steelhead trout and spring chinook salmon stage in the North Fork Clearwater River prior to ascending the fish ladder, but there is no documentation of gas bubble trauma in these fish (Ralph Roseburg per. comm.). Conversely, Dworshak Hatchery steelhead sac fry mortality by white spot disease was attributed to high supersaturation levels in nursery waters (Dave Owsley pers. comm.).

Sediment

Sediment data were collected from Potlatch River, Mission Creek, Cottonwood Creek, Big Canyon Creek, Little Canyon Creek, Whiskey Creek, Pine Creek, Orofino Creek, and Clear Creek (Murphy 1986). Murphy determined that every lower mainstem tributary transports large sediment loads into the mainstem Clearwater River during spring runoff. Conversely, these same tributaries often flow subsurface by mid to late summer (Kucera and Johnson 1986, Murphy 1986).

An intensive thunderstorm in the Lapwai Creek drainage, another major tributary of the LMCRR, caused an extensive fish kill in 1986 (Murphy and Johnson 1986). The researchers speculated that sediment-induced suffocation and agricultural pollutants were responsible for fish mortality.

Dworshak Dam acts as a "sediment trap" (Haber et al. 1978) on the North Fork probably resulting in little or no sediment input from this tributary.

The South Fork Clearwater has been impacted by mining and agriculture (Fishery Steering Committee (1957) in Lane, Lane and Nash 1981) and most likely contributes unnaturally high sediment loads to the mainstem.

The Middle Fork of the Clearwater River is formed by the Selway and Lochsa Rivers which are part of the National Wild & Scenic River Program (Lane, Lane and Nash 1981). This system flows through a predominantly unimpacted granitic channel and probably contributes little sediment to the LMCRR.

Suitability of LMCR Water Quality for Anadromous Salmonid Production

General Water Quality Parameters

Dissolved oxygen, pH, alkalinity, total suspended solids, TDS, nitrate, and nitrite are within a suitable range and should not limit anadromous production.

Dissolved Gas Levels

Lack of continuous gas level monitoring makes it difficult to determine the frequency and duration of gas supersaturation levels in the North Fork Clearwater River. Subsequently, we cannot determine potential impact on anadromous salmonid spawning and rearing with certainty.

The absence of gas bubble trauma in adult Dworshak Hatchery adult chinook salmon and steelhead trout may indicate that supersaturations do not exceed critical levels or durations harmful to adult chinook salmon and steelhead trout. However, the lack of external symptoms may also be due to the depth of water in which the adults stage prior to spawning. Adult chinook salmon and steelhead trout prefer to stage in deep water (Raleigh et al. 1984, 1986) and water depth compensates for high total gas pressure at a rate of 1 ATM/10 meters of water.

White spot disease documented in Dworshak Hatchery steelhead trout sac fry has been previously attributed to gas supersaturated water (Wood 1968 in Weitkamp and Katz 1980). Notably, both incidents occurred in artificial rearing environments. Shallow rearing facilities may intensify gas supersaturation effects.

The effect of Northfork Clearwater River gas supersaturation on the water quality of the LMCR remains to be documented. Our research shows that the North Fork contributes approximately 37% of mainstem water by volume on an annual basis. We contend that during periods of high Northfork gas levels, dilution by upriver mainstem water will maintain lower mainstem total gas pressure below the Environmental Protection Agency standard of 110% (APHA 1976). supersaturation of dissolved gases should not limit anadromous salmonid production in the LMCR.

Sediment

Excessive sediment input from tributaries into mainstem spawning reaches can detrimentally effect anadromous production. Publications reviewed by Gibbons and Salo (1973) listed reduced inter-and intra gravel water flow, alevin trapping, and egg smothering as primarily insults to spawning habitat.

The tributaries of the mainstem Clearwater River produce unnaturally large volumes of sediment during the spring. The ability of the Clearwater to transport large volumes of sediment during runoff most certainly influences the quality and quantity of anadromous salmonid spawning and rearing habitat in the LMCR. However, this river feature has never been studied for fisheries purposes.

Existing Information on Clearwater River Substrate

Published information on LMCR substrate exists for sites studied by Walker (1972), Brusven and MacPhee (1976), and Brusven and Trihey (1978). Walker characterized substrate by particle diameter in five riffles located between Ahsahka and Lewiston, Idaho (Table 13).

Table 13. Substrate particle diameter (cm) in sample sites, Clearwater River, 1970-71 (From Walker 1972).

Site	Average	Range
1	15.2	0.5 - 22.8
2	22.8	2.5 - 27.7
4	17.8	0.5 - 27.7
5	15.2	0.5 - 20.4

Brusven and MacPhee (1976) measured substrate at three intensive study sites in riffle-run habitats (Rkm 38, 50, and 72). They found substrate varied with location, slope, steepness of bank, and flow conditions. Cobble and rubble was generally unimbedded to 1/3 imbedded, except at the mouth of Orofino Creek (Rkm 72) where substrate was more imbedded (Brusven and MacPhee 1976). The authors attributed this to heavy sedimentation from Orofino Creek.

Brusven and Trihey (1978) evaluated substrate across 14 transects placed primarily in riffle-run habitats. They found that the LMCR could be subdivided into three reaches, each with different substrate characteristics. The effects of Lower Granite Dam on the Snake River created a reservoir pool extending 3.2 Km up river from the Clearwater/Snake River confluence. Substrate in the reservoir pool reach was characterized by silt, sand, and organic debris (Brusven and Trihey 1978).

A transition zone extends 3.2 Km upriver from the reservoir pool. Substrate in this reach was predominantly cobble and boulders 50-100% imbedded in sand (Brusven and Trihey 1978). The free flowing reach was by far the longest, extending from river Km 7.4 to 40.5. Brusven and Trihey found the substrate in this reach was composed of coarse sediments, cobbles, and boulders. Substrate was relatively unimbedded due to water velocity.

Relevance of Existing Substrate Information to Anadromous Salmonid Spawning and Rearing in the LMCR

Spawning:

Publications on substrate size preferences of spawning chinook salmon and steelhead trout are given in Table 14. In general, suitable substrate size and abundance increases with fish size and stream order, respectively (Bjornn and Reiser unpublished manuscript).

Table 14. Substrate diameter (cm) used by spawning chinook salmon and steelhead trout.

Species/Race of Fish	Substrate Diameter (cm)	Citation
Steelhead Trout	0.6-10.2 1.6-6.4	Hunter (1973) ^a Reiser and White (1981)
Summer Chinook	7.6-15.2 3.2-12.5	Burner (1951) Reiser and White (1981)
Fall Chinook	7.6-15.2 1.3-10.2 7.6-25.4	Burner (1951) Thompson (1972) ^b Huntington and Buell (1986)

^a Cited in Pauley, Bortz, and Sheppard (1983).

^b Cited in Bjornn and Reiser (unpublished manuscript).

Gravel stratification or armoring (Hynes 1972) also influences spawning by obstructing redd digging. Armoring occurs when floods or other flow disturbances disrupt normal bedload sediment transport. Large substrate is deposited over smaller, resulting in an un-friable stream bottom.

Substrate permeability is also important in spawning and egg development. Burner (1951) found that Entiat River summer chinook salmon adults abandoned developing redds on gravel bars with poor permeability or "subsurface percolation? Permeability of substrate to water flow is related to the embeddedness of the dominant substrate by finer materials. Throughout incubation water must flow through the egg pocket to oxygenate and flushout metabolites (Bjornn and Reiser, unpublished manuscript). Studies cited by Tappel and Bjornn (1983) related egg to fry survival and emergence to intergravel water flow and substrate composition by particle size. These papers indicate that the amount of small sediment embedding dominant particles affects redd suitability and fish survival: too many fines limit fish survival through emergence.

Rearing:

Substrate may play its most critical role during fall and winter rearing. Again, juvenile chinook salmon and steelhead trout are believed to move into mainstem rivers from tributaries in fall and hide in water substrate as temperatures decline below 4-5°C (Chapman and Bjornn 1969). Documentation of substrate size preferred by overwintering salmon and steelhead is rare and classification techniques vary by author. Edmundson et al. (1968) found that juvenile steelhead trout (65-185 mm) and age-0 chinook salmon overwintered between or under "rubble" substrate. Bjornn (1971) felt that by providing more "rock" than gravel cover in a study section in Big Springs Creek, he reduced juvenile steelhead fall emigration. Age-0 steelhead in a small Vancouver Island stream overwintered near 10-25 cm rocks (Bustard and Narver 1975). Habitat preference of subyearling steelhead trout in lower tributaries of the Clearwater River shifted from gravels and cobbles (based on a modified Wentworth Scale) in summer to cobbles and boulders in autumn (Johnson and Kucera 1985). Hillman et al. (1988) observed juvenile Wenatchee River steelhead and chinook salmon in pockets among "boulders" during winter.

Walker (1972), Brusven and MacPhee (1976), and Brusven and Trihey (1978) were interested primarily in invertebrate species diversity, density and biomass so they concentrated most of their substrate sampling efforts across riffles. Chinook salmon spawn mostly at the heads of riffles, tails of pools, around islands and mid-channel gravel bars in hydraulically uniform areas. Rearing juveniles feed in riffles but appear to rest and overwinter in shallow, low velocity shoreline margins, or in the absence of cover, in deep pools. Consequently, it is not possible to use existing substrate data to assess the spawning or rearing potential of the LMCR. Spawning gravel quality, abundance, and location and overwinter rearing habitat should be documented to assess the potential of the LMCR to produce salmon and steelhead trout.

Existing Information on LMCR Aquatic Invertebrate Production

Several studies compared pre and post impoundment LMCR invertebrate communities. Walker (1972) calculated pre-impoundment North Fork and LMCR invertebrate density, biomass, diversity, and drift periodicity. Walker determined that numbers of benthic invertebrates occurred in a range 1730-6240/m² in September and 24-76.5/M² in mid-winter. Diatoms were the dominant periphyton in all seasons. This researcher documented seven orders of insects including Ephemeroptera, Plecoptera, Trichoptera, Diptera, Coleoptera, Odonata, and Lepidoptera. Three species of the class Gastropoda and the classes Pelecypoda and Oligochaeta were also found in samples. Invertebrate density of all orders peaked in August, September, and March. Walker also found that drift occurred predominately from 12:00 p.m. to 4:00 a.m. Drift was highest in March and lowest in October. Ephemeropterans and Trichopterans were the most abundant insects in the drift. Walker concluded that the Northfork and LMCR held a stable and successional mature benthic community.

Differences in Walker's numerical classification of invertebrate abundance in 1972, and in Brusven and MacPhee's in 1976, prohibited an objective evaluation of pre and post-impoundment invertebrate population density or biomass. Brusven and MacPhee did state that there had been no significant shifts in the insect community during their study which started in 1973. Ninety-eight species of aquatic invertebrates exclusive of chironomids were collected in the LMCR by 1976. Drift, dominated by ephemeropterans and trichopterans, continued to occur at night (Brusven and MacPhee 1976, Stanton 1977). Additional information given by Brusven and MacPhee (1976) suggested that flow fluctuations along the shoreline favored recolonization by chironomid dipterans. Nonetheless, these authors concluded that as of 1976 the LMCR was rich in aquatic insects that had not been detrimentally affected by Dworshak Dam caused temperature and flow changes. However, long-term study was advised.

Accordingly, Brusven and Trihey conducted additional research from 1975 to 1977. Over 120 species of aquatic insects, exclusive of chironomids were collected in the LMCR during this time period (Brusven and Trihey 1978) (Table 15). Shifts in seasonal densities were noted for some species, but the authors emphasized that these shifts were minor and could not be tied conclusively to Dworshak Dam operations. Chironomids were most successful at colonizing shoreline areas subjected to water level fluctuations; as noted previously (Brusven and MacPhee 1976).

Filling Lower Granite pool by Lower Granite Dam on the Snake River in 1975 affected the aquatic insect community of the lower 6.4-7.4 Km (4-4.6 mi) of the Clearwater River (Brusven and Trihey 1978). These researchers found that by 1978 this river reach was dominated by chironomid midges and filter feeding caddisflies, Brusven and Trihey attributed the absence of a more riverine invertebrate community to the deposition of silt, sands, and organic debris associated with lower water velocities in the pool.

Brusven and Trihey (1978) felt that cooler summer and warmer winter water temperatures since Dworshak Dam completion could have future influence on the aquatic invertebrate community. They also reasoned that water velocity changes caused by dam releases were important determinants of invertebrate habitat. Subsequently, temperature and velocity effects were studied by Brusven and Haber (1981).

Brusven and Haber (1981) quantified water temperature change in terms of degree weeks or "the accumulation mean weekly temperature above 0°C during successive weeks. They found that Dworshak Dams temperature influence was twice as prevalent in the North Fork than in the LMCR; as would be expected. Invertebrate densities in the Northfork were higher than in the LMCR, but biomass was lower since 95% of Northfork invertebrates were chironomids. The researchers speculated that the temperature requirements of different invertebrate life stages and food sources may be partially responsible for this disparity (Brusven and Haber 1981).

Water depth, velocity, and substrate interact to influence invertebrate community structure (Brusven and Haber 1981). Brusven and Haber's Clearwater work showed that mayfly, caddis fly, and stone fly densities were 1500/m² at 15 cm water depth and 2200/m² at 30-40 cm water depth. Beyond these depths the densities of the three orders decreased. Brusven and Haber concluded that shallower shore areas contributed significant to insect density. Chironomids were an exception to this because the densities increased with depth.

Velocity also influenced invertebrate density. Density increased within a velocity range of less than 30 cm/sec to 90 cm from 1100 insects/m² to 3500 insects/m², respectively. Brusven and Haber questioned the meaningfulness of this data since velocity was measured at 0.6 water depth and insects inhabit the rock-water interface where velocity is probably negligible.

This study also documented higher insects densities in shoreline fluctuation zones with cobble substrate (127-m) than with sand substrate (<.1 m). Brusven and Haber added that substrate size is not an independent variable affecting invertebrate density, but interacts with mineral particles and algae surrounding the substrate, feeding strategy of the invertebrate, river discharge parameters, and permanency of watering.

Table 15. Checklist and distribution of insect species in the lower mainstem clearwater River (from Brusven and Trihey 1978).

Order	Species
Ephemeroptera	<u>Ameletus connectus, A. cooli, A. crgonensis A. similiar, A. sparsatus, A. validus, Baetis bicaudatus, Baetis parvusB. tricaudatus, Caenis latipennis, Centroptilum sp. #I, Centroptilum sp. #2, Cinygmula sp., Epeorus albertae, Epeorus longimanus, Ephemerella simulans, Ephemerella doddsi, Ephemerella edmundsi, Ephemerella flavilinea, Ephemerella grandis, Ephemerella hecuba, Ephemerella heterocaudata, Ephemerella hystrix, Ephemerella inermis-infreq., Ephemerella margarita, Ephemerella spinifera, Ephemerella tibialis, Heptagenia Criddlei, Heptagenia simplicoides, Heptagenia solitaria, Paraleptophlebia bicornuta, Paraleptophlebia debilis, Paraleptophlebia heteronea, Rithrogena hageni, Rithrogena robusta, Siphonurus columbianus, Stenonema reesi, Tricorythodes minutus</u>
Plecoptera	<u>Acroneuria californica, Acroneuria pacifica, Alloperla sp., Arcynopteryx sp., Brachyptera sp., Camia sp., Claassenia sp., Isogenus sp., Isoperla sp., Nemoura sp., Peltoperla sp., Pteronarcella badia, Pteronarcys sp., Taeniopteryx sp.</u>

Table 15. (Continued)

Order	Species
Coleoptera	<u>Amphizoa insolens, Ampunixus sp., Rychivs sp., Cleptelmis sp., Haliphus sp., Heterlimnius sp., Hydroporous sp., Narpus sp., Ordobrevia sp., Optioservus sp., Psephenus sp., Zaitzevia sp.</u>
Trichoptera	<u>Agapetus sp., Arctopsyche grandis, Athripsodes sp., Brachycentrus sp., Cheumatopsyche sp., Chimarra sp., Dicosmoecus sp., Dolophilodes sp., Drusines sp., Glossosoma SD., Helicopsyche sp., Hydroptila sp. A, Hydroptila sp. B, Leucotrichia sp., Lepidostoma sp. A, Lepidostoma sp. B, Leptoceridae (sp.), Micrasema sp., Neophylax sp., Neothremma sp., Neothrichia sp., Oecetis sp., Parapsycheelsis, Polycentropus sp., Psychoglypha sp., Psychomyia sp., Rhyacophila hyalinata, Rhyacophila vagrita, Rhyacophila verrula, Wormaldia</u> s p .
Diptera	<u>Antocha sp., Antherix vargiagata, Blephariceridae (sp.), chironomidae (spp.), Dicranota sp., Dolichopodidae (sp.), Empididae (sp.), Ephydriidae (sp.), Forcipomyia SP., Hexatoma sp., Limonia sp., Ormosia sp., Palpomyia sp., Philorus sp., Protanyderrus margarita, Prionocera sp. Simulium sp., Stratiomyidae (sp.), Tabanidae (sp.), Tipula sp.</u>
Odonata	<u>Ophiogomphus occidentis, Ophiogomphus severus</u>
Hemiptera	Corixidae
Neuroptera	<u>Sialis sp.</u>
Lepidoptera	<u>Parargyractis sp.</u>

Suitability of LMCR Invertebrate Production for Anadromous Salmonid Rearing

Assessing the suitability of the Northfork and LMCR invertebrate fauna for salmon and steelhead rearing is complicated. Aquatic insects metamorphose based on several habitat features. Successful colonization of different river sections depends upon the habitat preference of the insects and habitat availability. Time of day influences drift as does time of year. River discharge and temperature also may cause changes in invertebrate populations, but after 12 years of extensive research, changes noted in the Clearwater cannot be conclusively linked to Dworshak Dam operation because of the complicated and diverse life cycles of aquatic invertebrates.

Nonetheless, we can make some generalizations to derive a relative idea of the suitability of the invertebrate fauna of the Northfork and LMCR based on the research of Walker (1972) [Brusven and MacPhee (1976), Stanton (1977), Brusven and Trihey (1978), Brusven and Haber (1981).

The orders of aquatic invertebrates noted in the literature as being preferred by juvenile chinook salmon and steelhead trout (Tables 16 and 17) are found in the North Fork and LMCR (Table 15).

Densities of all orders of aquatic invertebrates peaks in late summer to early fall when juvenile salmon and steelhead in Idaho tributary streams may begin movement into mainstem rivers (Chapman and Bjornn 1969, Kucera and Johnson 1986). A secondary density peak occurs in March when water temperatures warm above 4-5 C° and juvenile salmonids may end winter dormancy.

Ephemeropteran, trichopteran, and plecopteran densities were highest in shallow, low to moderate velocity near shore areas often preferred by rearing juvenile salmonids (Chapman and Bjornn 1969, Everest and Chapman 1972, Bustard and Narver 1975, Shepard and Johnson 1985). Chironomid dipterans were densely distributed at all depths across the channel and were most adept at colonizing fluctuation zones.

Table 16. Taxonomic composition of invertebrates in stomach samples taken from juvenile chinook salmon as indicated in the literature.

Taxon	Percent Numbers	Fish Size	Fish race	Citation
Diptera	80 ^a			
Trichoptera	3			
Terrestrials	2	34-66	Fall	Dauble, Gray, & Page (1980)
Zooplankton	14			
Other	1			
Diptera	82.9 ^b			
Trichoptera	4.4			
Hemiptera	3.2	35-50	Fall	Becker (1970)
Others	9.5			
Diptera	57.9 ^c			
Coleoptera	11.9			
Hemiptera	3.3	43-120	----	Chapman & Quistorff (1938)
Plecoptera	3.3			
Others	6.6			
Diptera	78.3 ^d			Brusven & MacPhee (1976)
Hemiptera	5.0			
Trichoptera	4.4	36-85	Fall	
Others	12.3			

a Chironomidae larvae composed 78% of aquatic insects consumed

b Chironomidae larvae and adults composed 81% of aquatic insects consumed

c Chironomidae larvae and adults composed 76.4% of aquatic insects consumed

d Chironomidae larvae and adults composed 95% of aquatic insects consumed

Table 17. Taxonomic composition of invertebrates in stomach samples taken from juvenile steelhead trout as indicated in the literature.

Taxon	Percent Numbers	Fish Size	Citation
Diptera	50.3		
Coleoptera	22.9		
Hymenoptera	10.5	46-232	Chapman & Quistorff (1938)
Orthoptera	7.8		
Others	8.5		
Trichoptera	50.5		
Diptera	36.3		
Hemiptera	5.1	66-175	Shapolov & Taft (1954)
Coleoptera	4.8		
Hymenoptera	1.2		
Others	2.1		
Diptera	38.0 ^a		
Ephemeroptera	25.5		
Trichoptera	7.6		
Coleoptera	7.1	49.0-55.2	Johnson & Johnson (1981)
Homoptera	5.5		
Hymenoptera	4.2		
Plecoptera	3.6		
Others	8.5		

a Chironomidae larvae and adults composed 29.9% of all insects consumed

RESEARCH NEEDS

There is no information on the current use of the LMCR by spawning or rearing anadromous salmonids. Increasing hatchery pre-smolt and smolt releases into the mainstem and its tributaries may be influencing upriver production by saturating rearing habitat. Obviously, we need to document and if possible quantify current spawning and rearing in the LMCR.

Anadromous fish habitat in the LMCR has never been evaluated. A thorough assessment of the quality and quantity of this habitat, especially spawning and rearing substrate, will be a prerequisite to determining the ability of the entire Clearwater River drainage to produce and sustain natural anadromous salmonid production.

Quantification of channel cross sectional water depth, velocity, and substrate composition in a manner compatible with instream flow evaluation is necessary if we intend to manage Dworshak Dam operations to accommodate optimal anadromous salmonid production in the LMCR.

A conclusive description of the relationship between Dworshak Dam discharge and the LMCR temperature regime is unavailable. The ability to predict the effect of various Dworshak Dam discharge volumes on downriver water temperatures would be a valuable management tool.

This report was based on the assumption that summer and fall chinook incubation to emergence will require 1,000 tu's. Verification of this assumption would better enable researchers to recommend the ideal stock of salmon for re-introduction into the LMCR. This procedure would also give us a better idea of smoltification and outmigration timing. Perhaps, some fish are migrating from the LMCR during low flow periods after Water Budget augmentation.

The LMCR is not an exceedingly productive river. Information on the food habits of rearing juvenile salmon and steelhead will be critical in determining the ability of the lower Clearwater to produce these fish. We should determine what juveniles are feeding on, when they are feeding, and the densities of preferred food organisms. Also, it would be useful to compare the diets of hatchery released fish to wild fish.

Lack of continuous gas level monitoring makes it difficult to determine the frequency and duration of gas supersaturation levels in the North Fork Clearwater River. Subsequently, we cannot determine potential impact on anadromous salmonid spawning and rearing with certainty. More consistent gas level monitoring is necessary to insure that gas levels in the North Fork are being maintained within the 110% total gas pressure EPA standard.

SUMMARY

Lower mainstem Clearwater River water temperature varies with proximity to Dworshak Dam. Water at Peck (14.8 km downriver from Dworshak Dam) is warmer in the winter and cooler in the summer than water at Spalding (39 km downriver from Dworshak Dam).

Average lower mainstem Clearwater River temperatures calculated using USGS gaging station data from Peck and Spalding for the time period 1972-1987 fall within the range of temperatures tolerated by all life stages of summer and fall chinook salmon.

Absolute maximum water temperatures during June and July at both Peck and Spalding should be of no direct threat to adult summer or fall chinook salmon staging or spawning in the lower mainstem Clearwater River.

Absolute maximum September water temperatures capable of decreasing summer chinook salmon egg survival occur infrequently and for very short periods of time and probably would not influence natural summer chinook reproduction in the lower mainstem Clearwater River.

Absolute minimum water temperatures during December, January, and February occur that have the potential to decrease overwinter survival of age-0 summer chinook and incubating fall chinook eggs in some years, if the overwinter habitat available in the lower mainstem Clearwater River is inadequate or intra-gravel freezing occurs.

Maximum lower mainstem Clearwater River summer water temperatures are not directly lethal to rearing chinook salmon or steelhead trout, but may cause decreased growth.

Based on the temperature regime of the lower mainstem Clearwater River age-1+ summer chinook salmon produced naturally in the river could be near the 102-127 mm critical size associated with smoltification, concurrent to augmentation of the Water Budget assuming, rearing occurs in the Clearwater. More work on Summer chinook salmon rearing and outmigration behavior is needed.

Fall chinook salmon would probably emerge from mid-May to early June in the lower mainstem Clearwater River concurrent to peak annual discharge, but may not be physiologically capable of smolting until August or September. Successful outmigration past Lower Granite Dam concurrent to the optimum conditions provided by the Water Budget would depend on the migration behavior of newly emerged fry. Information

pertaining to Snake River fall chinook age at outmigration is scarce.

Dworshak Dam releases are obviously affecting anadromous fish habitat in the LMCR. However, there is not enough information on this habitat to quantify dam effects.

Water quality in the LMCR is suitable for natural production of chinook salmon and rearing of steelhead trout.

Information on substrate of the LMCR is inadequate for fisheries management purposes.

Past research indicates that the invertebrate production of the LMCR should meet the rearing needs of juvenile salmon and steelhead trout.

LITERATURE CITED

- APHA 1976 (American Public Health Association). 1976. Standard methods for the examination of water and wastewater, 14th edition. American Public Health Association, Washington, D.C, USA.
- Alderice, D.F., W.P. Wickett, and J.R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal of the Fisheries Research Board of Canada 15(2)229-249.
- Armour, C.A. (unpublished manuscript). Guidance for evaluating and recommending temperature regimes to protect fish. U.S. Fish and Wildlife Service Biological Report 88.
- Ball, K. and W. Cannon. 1974. Evaluation of game and rough fish populations below Dworshak Dam and relationship to change in water quality. Job Performance Report to the U.S. Army Corps of Engineers. Contract No. 14-16-0001-4842FS. Idaho Fish and Game.
- Ball, K. and S. Pettit. 1974. Evaluation of game and rough fish populations below Dworshak Dam and relationship to changes in water quality. Job Performance Report. Project DSS-29-4. Idaho Fish and Game.
- Becker, C.D. 1970. Temperature, timing, and seaward migration of juvenile chinook salmon from the central Columbia River. Battelle Northwest Laboratories Report BNWL-1472. 21p. From selected water resources abstract 4(18):30. SFA 17(1).
- Becker, C.D., D.H. Fickeisen, and J.C. Montgomery. 1981. Assessment of impacts from water level fluctuations on fish in the Hanford Reach, Columbia River. PNL-3813, Pacific Northwest Laboratory, Richland Washington.
- Becker, C.D., D.A. Neitzel, and D.H. Fickeisen. 1982. Effects of dewatering on chinook salmon redds: Tolerance of four developmental phases to daily dewaterings. Transactions of the American Fisheries Society 111:624-637.
- Becker, C.C., D.A. Neitzel, and C. Scott Abernathy. 1983. Effects of dewatering on chinook salmon redds: tolerance of four development Phases to One-time dewatering. North American Journal of Fisheries Management 3:373-382.

- Bell, R.J. 1964. Reintroduction of steelhead trout into the South Fork of the Clear-water River and the Lemhi River, 1963. Contract No. 14-17-0001-779. Project No. 221.2-IDA-1.3. Idaho Fish and Game.
- Bjornn, T.C. 1969. Embryo survival and emergence studies. Salmon and Steelhead Investigations. Job Completion Report, Project F-049-R-07. Idaho Fish and Game.
- Bjornn, T.C. and D.W. Reiser. (unpublished manuscript) Habitat requirements of salmon, char, and trout in streams. Contribution No. 352 from the Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow, Idaho.
- Brett, J.R. 1952. Temperature tolerance in young Pacific salmon genus Oncorhynchus. Journal of the Fisheries Research Board of Canada 9(6):256-323.
- Brusven M.A. and C. MacPhee. 1976. The effects of river fluctuations resulting from hydroelectric peaking on selected invertebrates and fish. OWRT Technical Completion Report. Project No. A-035-IDA. University of Idaho.
- Brusven, M. and E.W. Trihey. 1978. Interacting effects of minimum flow and fluctuating shorelines on benthic stream insects. Technical completion report project no. A-052-IDA. Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho.
- Brusven, M.A. and D.F. Haber. 1981. Effects of power peaking cycles from simulated fourth generator discharges on benthic invertebrates in the Clearwater River. Project Completion Report to the United States Department of the Interior Fish and Wildlife Service. Contract No. 14-16-0001-80176.
- Burner, C.J. 1951. Characteristics of spawning nests of Columbia River Salmon. U.S. Fish and Wildlife Service Fisheries Bulletin 61:97-110.
- Bustard, D.R. and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 32(5):667-680.
- Chapman, W.M. and E. Quistorff. 1938. The food of certain fishes of North Central Columbia River Drainage, in particular, young chinook salmon and steelhead trout. Department of Fisheries, State of Washington. Biological Report No. 37A.

- Chapman, D.W. and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. In Symposium on salmon and trout streams. H.R. MacMillan Lectures in Fisheries, February, 1968. Edited by T.G. Northcote. University of British Columbia, Vancouver, B.C. pp. 153-176.
- Chapman, D.W., D.E. Weitkamp, T.L. Welsh, M.B. Dell, and T.H. Schadt. 1986. Effects of river flow on the distribution of chinook salmon redds. Transaction of the American Fisheries Society 115(4):537-547.
- Coble, D.W. 1961. Influence of water exchange and dissolved oxygen in redds on survival of steelhead and trout embryos. Transactions of the American Fisheries Society 90(4):469-474.
- Combs, B.D. 1965. Effect of temperature on the normal development of salmon eggs. Progressive Fish-culturist 27(3):134-137.
- Combs, B.D. and R. E. Burrows. 1957. Threshold temperatures for the normal development of chinook eggs. Progressive Fish-Culturist 21(4):165-168.
- Coutant, C.C. 1970. Thermal resistance of adult coho (O. kisutch) and jack chinook (O. tschawytscha) salmon, and adult steelhead trout (Salmo gairdneri) from the Columbia River. Atomic Energy Commission Research and Development Report. Battelle Memorial Institute, Pacific Northwest Laboratories, Richland, Washington.
- Cushman, R.M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5:330-339.
- Dauble, D.D., R.H. Gray, and T.L. Page. 1980. Importance of insects and zooplankton in the diet of 0-age chinook salmon (O. tschawytscha) in the central Columbia River. Northwest Science 54(4):253-258.
- Decker-Hess, J. and P. Clancey. 1984. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Annual progress report to the U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. Contract No. DE-AI79-83BP39641. Project No. 81S-5.

- DeHart, M. and M.H. Karr. 1987. Fish Passage Managers Annual Report. BPA Project No. 87-127.
- Edmundson, E., F.E. Everest, and D.W. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 25(7):1453-1464.
- Everest, F.H. and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29(1):91-100.
- Gibbons, D.R., and E.O. Salo. 1973. An annotated bibliography on the effects of logging on fish of the western United States and Canada. United States Technical Report PNW-10, Pacific Northwest Forest and Range and Experimental Station, Portland, Oregon, USA.
- Gordon, C.D., D.F. Haber, E.L. Michalson and J.J. Peebles. 1970. An environmental survey of the Lower Clearwater River. Water Resources Institute, University of Idaho Scenic Rivers Unit, Moscow, Idaho.
- Haber, D.F., B. Moore, and W. Hicks. 1978. A review of the impacts of fluctuating flows on the lower Clearwater River and recommendations for future studies. Contract No. DACW68-76M-2586, Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho.
- Hillman, T., D.W. Chapman, and J.S. Griffith. 1988. Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. A report to Chelan County Public Utility District, Washington.
- Horner, N. and T.C. Bjornn. 1981. Status of upper Columbia and Snake River summer chinook salmon in relation to the Endangered Species Act. Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho.
- Hoss, S.A. 1970a. Reintroduction of salmon and steelhead into portions of the Clearwater River drainage. Contract No. 14-17-0001-1860. Project No. 161.22A. Idaho Fish and Game.
- Hoss, S.A. 1970b. Evaluation of salmon and steelhead reintroductions into the Clear-water River drainage. Contract No. 14-17-0001-1857. Project No. 1612-B. Idaho Fish and Game.

- Hoss, S.A. 1971. Evaluation of salmon and steelhead reintroductions into the Clearwater River drainage. Contract No. 14-17-0001-2043. Project No. 160.2B. Idaho Fish and Game.
- Hoss, S.A. 1972. Evaluation of salmon and steelhead reintroductions into the Clearwater River drainage. Contract No. NA208-00-21(N)72. Project No. 028180312. Idaho Fish and Game.
- Hoss, S.A. 1974. Evaluation of development of Clearwater River spring chinook stocks. Contract No. 03030208-3. Project No. 28272402. Idaho Fish and Game.
- Hoss, S.A. 1975. Clearwater River development of spring chinook and steelhead stocks. Contract No. 03-5-208-00025. Project No. 88272402. Idaho Fish and Game.
- Howell, P., K. Jones, D. Scarnecchia, L. LaVoy, W. Kendra, and D. Ortman. 1985. Stock assessment of Columbia River Anadromous salmonids. Volume I: chinook, coho, chum and sockeye salmon stock summaries. Final Report to U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. Contract No. DE-AI79-84BP12737, Project No. 83-335.
- Huntington, C.W., and Buell and Associates, Incorporated. 1985. Deschutes River spawning gravel study, Volume I. Final Report prepared for U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Contract No. DE-AC79-83BP13102 Project No. 83-423.
- Hynes, H.B.N. 1972. The ecology of running waters. University of Toronto Press. 555p.
- Irving, J.S. and T.C. Bjornn. 1980. Status of Snake River fall chinook salmon in relation to the Endangered Species Act. Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho.
- Johnson, J.H. and E.Z. Johnson. 1981. Feeding periodicity and diel variation in diet composition of subyearling coho salmon and steelhead in a small stream during summer. Fishery Bulletin 79(2):370-376.
- Johnson, J.H. and P.A. Kucera. 1985. Summer-Autumn habitat utilization of subyearling steelhead trout in tributaries of the Clearwater River, Idaho. Canadian Journal of Zoology 63:2283-2290.

- Kucera, P.A. and D.B. Johnson. 1986. A biological and physical inventory of the streams within the Nez Perce Reservation. Juvenile steelhead survey and factors that affect abundance in selected streams in the lower Clearwater River Basin, Idaho. Final Report to the U.S. Department of Energy, Bonneville Power administration, Division of Fish and Wildlife. Contract No. DE-AI79-83BP10068, Project No. 82-1.
- Lane and Lane Associates, and D. Nash. 1981. The Clearwater River Indian Fisheries and Lewiston Dam. A report prepared for the Bureau of Indian Affairs, U.S. Department of the Interior, Portland, Oregon. 163 pp.
- Lavier, D.C. 1976. Investigative reports of Columbia River fisheries project. Section G. Prepared for Pacific Northwest Regional Commission.
- Leitritz, E. and R.C. Lewis. 1980. Trout and salmon culture (hatchery methods). California Department of Fish and Game. Fisheries Bulletin 164. 197 p.
- Lindland, R.L. and B. Bowler. 1986. Spring chinook and steelhead stocks. Columbia River Fisheries Development Program. Idaho Department of Fish and Game. A report to the National Marine Fisheries Service Contract No. 85-ABH-00019.
- Lukens, J.R. 1982. River and Stream Investigations. Clearwater River steelhead investigations. Job Performance Report. Project F-73-R-4. Idaho Department of Fish and Game.
- Miller, W. H. 1969. Factors influencing migration of chinook salmon fry (O. tshawytscha) in the Salmon River. Ph.D. Dissertation, University of Idaho, Moscow, Idaho. 80p.
- Miller, W.H. 1987. A review of Dworshak National Fish Hatchery mitigation record. U.S. Fish and Wildlife Service, Dworshak Fisheries Assistance Office, Ahsahka, Idaho.
- Miller, W.H., T.C. Coley, and R.B. Roseburg. 1987. Dworshak Fisheries assistance Office. Annual Report. Report No. FAO-2.
- Murphy, P.K and S. Kieffer. (in press). Clearwater River subbasin plan. A report to the Northwest Power Planning Council and the Agencies and Tribes of the Columbia Basin Fish and Wildlife Authority.

- Murphy, P.K. 1985. An Analysis of water quantity/quality and spawning/rearing habitat for selected streams within the Nez Perce Reservation. Technical Report 85-1. Department of Fisheries Management, Nez Perce Tribe, Lapwai, Idaho.
- Murphy, P.K. 1986. Water quality status report for lower Clear-water River Tributaries, Nez Perce Reservation, Idaho Water Year 1986. Submitted to The Bureau of Indian Affairs, Department of Fisheries Resource Management, Nez Perce Tribe, Lapwai, Idaho.
- Murphy, P.K., Johnson, D.B. 1986. A review of the 1986 fish kill in Lapwai Creek, Lower Clearwater River Subbasin, Nez Perce Reservation, Idaho. Nez Perce Tribe Technical Report 86-7. Department of Fisheries Resource Management, Nez Perce Tribe.
- Neitzel, D.A. and C.D. Becker. 1985. Tolerance of eggs, embryos, and alevins of chinook salmon to temperature changes and reduced humidity in dewatered redds. Transactions of the American Fisheries Society 114(2):267-273.
- Olson, P.A., and R.F. Foster. 1955. Temperature tolerance of eggs and young of Columbia River chinook salmon. Transactions of the American Fisheries Society 85:203-207.
- Pauley, G.B., B.M. Bortz, and M.F. Sheppard. 1983. Species profile: life histories and environmental requirements (Pacific Northwest) - steelhead trout. Draft report. U.S. Fish and Wildlife Service National coastal Ecosystems team, Slidell, LA.
- Pettit, S.W. 1976. Evaluation of game and rough fish populations below Dworshak Dam and relationship to changes in water quality. Job Completion Report. Project DSS-29. Idaho of Fish and Game.
- Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. U.S. Department of the Interior Fish and Wildlife Service, Washington, D.C. 516p.
- Raleigh, R.F., T. Hickman, R.X. Solomon, and P.C. Nelson. 1984. Western Energy and Land Use Team, Division of Biological Services, Research and Development, Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC.

- Raleigh, R.F, W.J. Miller, and P. C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. Biological report 82(10.122) Performed for the National Ecology Center, Division of Wildlife Contaminant Research, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.
- Reiser, D.W. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. In W.R. Meehan, editor. Influences of forest and rangeland management on anadromous fish habitat in Western North America. USDA Forest Service, General Report PNW-96. Pacific Northwest Forest and Experimental Station, Portland Oregon, USA.
- Reiser, D.W. and T.A. Wesche. 1979. In situ freezing as a cause of mortality in brown trout eggs. The Progressive Fish Culturist 41(2):58-60.
- Reiser, D.W. and R.G. White. 1981. Influence of stream flow reductions on salmonid embryo development and fry quality. Research Technical Completion Report Project A-058-IDA. Idaho Water and Energy Resources Research Institute, University of Idaho, Moscow, Idaho.
- Reiser, D.W. and R.G. White. 1983. Effects of complete redd dewatering on salmonid egg-hatching success and development of juveniles. Transactions of the American Fisheries Society 112(4)532-540.
- Richards, M. 1967. Appraisal of project results for salmon and steelhead reintroduction and introductions into the Clearwater River Drainage, Idaho. Contract No. 14-17-0001-1266. Project No. 161-1B-IDA. Idaho Fish and Game.
- Richards, M. 1969. Evaluation of salmon and steelhead reintroductions into the Clearwater River drainage, Idaho. Contract No. 14-17-0001-1682. Project No. 1612-2B. Idaho Fish and Game.
- Shapolov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (S. gairdneri) and silver salmon (O. kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. State of California Department of Fish and Game Fish Bulletin No. 98.

- Sheppard, J.D. and J.H. Johnson. 1985. Probability-of-use for depth, velocity and substrate by yearling coho salmon and steelhead trout in Lake Ontario tributary streams. North American Journal of Fisheries Management 5:277-282.
- Silver, S.J., C.E. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook embryos at different water velocities. Transactions of the American Fisheries Society 92(4):327-343.
- Stabler, D.F., R.G. White, R.R. Ringe, T.C. Bjornn. 1976. Effects of altered flow regimes, temperatures and river impoundment on adult steelhead and chinook salmon. Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho.
- Tappel, P.D., and T.C. Bjornn. 1983. A new method of relating size of spawning gravel to salmonid embryo survival. North American Journal of Fisheries Management 3:123-135.
- United States Army Corps of Engineers. 1986. Water Control Manual for Dworshak Dam and Reservoir, North Fork Clearwater River, Idaho.
- Walker, R. 1972. Benthos and periphyton communities in riffles of the Clearwater River, Idaho. Unpublished M.S. Thesis. University of Idaho. 42p.
- Weitkamp, D.E. and M. Katz. 1980. A review of dissolved gas supersaturation literature. Transactions of the American Fisheries Society 109:659-702.
- Welsh, T.L. 1961. Reintroduction of spring and summer run chinook into the Selway River, Clearwater River drainage, Idaho. Contract No. 14-17-000-379. Project No. 912.2-051.3. Idaho Fish and Game.
- Welsh, T.L. 1963. Reintroduction of spring and summer run chinook into the Selway River, Clearwater River drainage, Idaho. Contract No. 14-17-000-635. Project No. 221.2-IDA-1.3. Idaho Fish and Game.
- White, R.G., A.E. Bingham, J.H. Milligan, M.A. Brusven, and C.A. Corraino. 1985. Effects of reduced stream discharge on fish and aquatic macroinvertebrate populations Phase II. Idaho Water Resources Institute, University of Idaho, Moscow, Idaho.

Zar, J.H. 1984. Biostatistical Analysis. Second edition.
Prentice-Hall, Incorporated, Englewood Cliffs, New
Jersey.

APPENDIX A

Table A1.
SNAKE RIVER SUMMER CHINOOK

AVERAGE MAXIMUM WATER TEMPERATURE AT PECK, ID
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1986

DAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1	9.9	15.1	18.8	16.0	12.5	8.5	5.3	3.5	3.1	4.3	5.7	7.9	9.9
2	10.2	14.9	18.9	15.7	12.4	8.2	5.2	3.6	3.2	4.3	5.7	8.1	10.2
3	10.4	15.0	18.9	15.7	12.2	8.2	5.3	3.6	3.1	4.1	5.8	8.0	10.4
4	10.5	15.0	18.6	15.5	12.1	8.3	5.1	3.4	3.0	4.1	6.0	8.0	10.5
5	10.8	15.2	18.8	15.2	12.0	8.0	5.0	3.1	3.1	4.2	6.3	7.8	10.8
6	11.0	15.6	18.9	14.8	11.9	8.0	4.8	3.0	3.0	4.2	6.6	7.6	11.0
7	11.2	15.9	18.8	14.6	11.8	7.8	4.9	3.2	2.9	4.4	6.6	8.0	11.2
8	11.3	16.0	18.8	14.2	11.5	7.6	4.8	3.1	3.0	4.5	6.5	8.2	11.3
9	11.5	15.8	19.2	14.4	11.3	7.2	4.9	3.1	2.8	4.6	6.6	8.4	11.5
10	11.5	16.1	18.7	14.3	11.2	6.9	4.9	3.2	2.8	4.8	6.6	8.3	11.5
11	11.6	16.2	18.6	14.0	11.0	6.6	4.8	3.3	2.8	4.9	6.6	8.3	11.6
12	11.6	16.5	18.5	13.8	10.8	6.4	4.9	3.3	2.6	4.7	6.7	8.3	11.6
13	11.5	16.6	17.9	14.0	10.8	6.1	4.8	3.1	2.7	4.8	6.9	8.9	11.5
14	11.6	16.5	17.8	13.8	10.7	6.0	4.6	3.1	2.7	4.8	7.2	9.1	11.6
15	11.7	17.1	17.7	13.9	10.8	6.1	4.4	2.9	2.6	4.9	7.2	8.7	11.7
16	11.7	15.6	18.0	13.7	10.6	6.5	4.4	2.8	3.0	5.0	7.1	8.3	11.7
17	11.8	16.8	17.6	13.5	10.5	6.6	4.1	2.8	3.2	4.9	7.3	8.3	11.8
18	11.9	16.6	17.3	13.4	10.5	6.5	4.1	2.8	3.2	4.9	7.3	8.9	11.9
19	12.1	17.1	17.4	13.4	10.3	6.4	4.0	2.8	3.2	4.9	7.2	9.5	12.1
20	12.3	17.3	17.2	13.4	10.3	6.4	4.0	2.8	3.3	5.1	7.4	9.8	12.3
21	12.5	17.6	16.8	13.3	10.1	6.1	3.9	2.9	3.4	5.0	7.4	9.8	12.5
22	12.8	18.0	16.5	13.2	9.8	6.1	4.0	2.9	3.5	5.4	7.8	9.7	12.8
23	13.1	18.1	16.2	13.1	9.5	5.9	3.8	2.9	3.6	5.3	8.3	9.4	13.1
24	13.3	18.1	16.3	12.9	9.3	5.9	3.7	3.1	3.7	5.5	8.3	9.1	13.3
25	13.7	18.2	16.2	12.8	9.3	5.9	3.5	2.9	3.9	5.5	7.8	9.1	13.7
26	13.8	18.2	16.8	12.8	9.1	5.6	3.5	2.8	3.9	5.5	7.8	9.4	13.8
27	14.0	18.3	16.9	12.8	9.0	5.1	3.8	3.1	4.2	5.6	7.8	9.4	14.0
28	14.6	18.3	16.5	12.6	8.9	5.3	3.8	3.2	4.1	5.5	7.8	9.4	14.6
29	14.9	18.4	16.0	12.7	8.6	5.2	3.9	3.1	4.0	5.6	7.9	9.7	14.9
30	15.0	18.4	16.0	12.6	8.7	5.1	3.7	3.0		5.8	7.8	9.8	15.0
31	15.0	18.1	16.1		8.4		3.7	3.1		5.6		9.9	15.0
AVG	12.1	16.8	17.6	13.9	10.5	6.6	4.4	3.1	3.2	4.9	7.1	8.8	12.1
T.U.'S				210.0	325.9	64.5							
SUM							600.4						

SIX HUNDRED TEMPERATURE UNITS WOULD BE AVAILABLE BY NOVEMBER 8

Table A2.
SNAKE RIVER SUMMER CHINOOK

AVERAGE MINIMUM WATER TEMPERATURE AT PECK, ID
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1986

DAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1	8.9	13.6	16.4	14.2	11.5	7.7	4.6	3.1	2.5	3.7	5.0	7.0	8.9
2	9.2	13.4	16.9	14.0	11.5	7.7	4.5	3.1	2.4	3.6	4.9	7.0	9.2
3	9.3	13.6	16.9	14.0	11.4	7.7	4.5	3.2	2.2	3.7	5.0	7.2	9.3
4	9.5	13.8	16.6	14.0	11.3	7.8	4.6	2.7	2.2	3.6	5.2	7.0	9.5
5	9.4	13.8	16.8	13.6	11.0	7.6	4.4	2.8	2.2	3.8	5.4	6.8	9.4
6	9.9	14.0	16.9	13.1	11.0	7.5	4.5	2.6	2.4	3.8	5.8	6.8	9.9
7	10.1	14.2	16.4	12.9	10.9	7.3	4.5	2.7	2.2	3.9	5.8	6.9	10.1
8	10.3	14.5	16.5	13.0	10.5	7.2	4.3	2.9	2.0	4.0	5.7	7.4	10.3
9	10.4	14.3	16.9	12.9	10.5	6.6	4.3	2.6	2.0	4.2	5.8	7.4	10.4
10	10.4	14.2	16.8	13.0	10.5	6.3	4.1	2.7	2.0	4.3	5.8	7.4	10.4
11	10.5	14.4	16.4	12.8	10.3	6.1	4.0	2.6	2.1	4.3	5.8	7.2	10.5
12	10.7	14.4	16.4	12.7	10.1	5.8	3.9	2.7	2.2	4.3	5.8	7.4	10.7
13	10.5	14.3	16.0	12.7	9.9	5.6	3.9	2.5	2.2	4.4	5.9	7.6	10.5
14	10.6	14.5	16.0	12.6	9.8	5.5	3.8	2.3	2.0	4.3	6.1	8.1	10.6
15	10.7	15.1	15.6	12.5	9.8	5.6	3.6	2.0	2.1	4.3	6.2	7.8	10.7
16	10.8	15.3	15.5	12.6	9.8	5.4	3.6	2.0	2.4	4.4	6.4	7.3	10.8
17	11.0	15.2	15.5	12.5	9.7	6.0	3.6	2.3	2.6	4.4	6.3	7.2	11.0
18	11.0	14.9	15.0	12.5	9.6	5.9	3.5	2.1	2.8	4.4	6.3	7.5	11.0
19	10.9	15.2	15.1	12.4	9.6	5.7	3.6	2.2	2.8	4.4	6.4	8.1	10.9
20	11.1	15.4	14.7	12.5	9.7	5.6	3.5	2.3	2.9	4.5	6.4	8.7	11.1
21	11.5	15.5	14.9	12.3	9.5	5.7	3.6	2.4	2.8	4.6	6.4	8.7	11.5
22	11.6	16.1	14.6	12.2	9.1	5.6	3.4	2.2	2.9	4.7	6.7	8.3	11.6
23	12.0	16.1	14.5	12.2	8.8	5.7	3.3	2.4	3.0	4.9	7.1	8.0	12.0
24	12.2	16.5	14.5	12.0	8.6	5.4	3.2	2.4	3.0	4.9	7.3	8.1	12.2
25	12.2	16.4	14.2	11.8	8.6	5.3	3.0	2.4	3.3	5.0	6.8	8.2	12.2
26	12.3	16.6	14.6	11.8	8.5	4.6	3.0	2.5	3.5	5.1	6.7	8.3	12.3
27	12.5	16.2	15.3	11.9	8.3	4.4	3.1	2.6	3.5	5.0	6.7	8.3	12.5
28	13.0	15.9	14.9	12.0	8.1	4.6	3.3	2.8	3.6	4.9	6.9	8.4	13.0
29	13.3	15.8	14.6	11.8	8.1	4.7	3.3	2.7	3.5	4.8	6.8	8.6	13.3
30	13.4	16.0	14.4	11.8	8.0	4.8	3.4	2.6		4.8	6.8	8.8	13.4
31		16.3	14.5		7.9		3.4	2.6		4.9		8.8	
AVG	11.0	15.0	15.6	12.7	9.7	6.0	3.8	2.5	2.6	4.4	6.1	7.8	11.0
T.U.'S				194.7	301.7	107.5							
SUM						603.9							

SIX HUNDRED TEMPERATURE UNITS WOULD BE AVAILABLE BY NOVEMBER 16

Table A3.
SNAKE RIVER SUMMER CHINOOK

AVERAGE MAXIMUM WATER TEMPERATURE AT SPALDING, IDAHO
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1986

DAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1	11.2	16.3	19.6	16.7	13.2	8.3	4.9	2.6	3.3	5.2	7.1	9.5	11.2
2	11.5	16.0	19.6	16.4	13.2	8.4	4.9	2.3	3.3	5.4	6.8	9.0	11.5
3	11.4	16.1	19.9	16.1	13.1	8.3	4.8	2.7	3.5	5.1	7.0	9.5	11.4
4	11.9	16.2	19.6	16.3	12.9	8.3	4.7	2.8	3.1	5.3	7.2	9.2	11.9
5	12.0	16.6	19.7	16.3	12.8	8.0	4.5	2.5	2.9	5.3	7.5	9.1	12.0
6	12.0	16.8	19.7	16.0	12.7	7.9	4.6	2.5	2.8	5.5	7.6	8.9	12.0
7	12.2	16.7	19.9	15.8	12.6	8.0	4.5	2.4	3.0	5.2	7.6	9.1	12.2
8	12.3	16.9	19.4	15.5	12.5	7.8	4.5	2.5	3.0	5.7	7.5	9.5	12.3
9	12.3	17.3	19.6	14.8	12.0	7.4	4.3	2.5	2.9	5.6	7.9	9.8	12.3
10	12.4	17.2	19.9	14.8	11.9	7.3	4.4	2.3	2.9	5.7	8.1	9.9	12.4
11	12.7	17.4	19.8	14.6	11.7	6.7	4.5	2.3	3.1	5.9	8.3	9.8	12.7
12	12.6	17.5	19.3	14.4	11.4	6.5	4.4	2.6	3.4	5.7	8.3	9.8	12.6
13	12.3	18.0	18.9	14.5	11.4	6.2	4.1	2.7	3.5	5.8	8.5	10.3	12.3
14	12.5	18.1	18.9	14.7	11.6	5.8	3.9	2.9	3.4	6.1	8.8	10.5	12.5
15	12.6	18.4	18.8	14.6	11.5	5.5	3.7	2.6	3.6	6.1	8.6	10.0	12.6
16	12.8	18.5	18.6	14.5	11.4	5.9	3.8	2.7	3.8	6.1	8.7	9.7	12.8
17	12.9	18.8	18.5	14.3	11.0	6.2	3.8	2.5	3.9	6.0	8.9	9.6	12.9
18	13.2	18.4	18.3	14.1	10.8	6.2	3.8	2.9	4.2	6.0	8.7	9.7	13.2
19	13.4	18.2	17.9	14.0	10.8	6.0	3.7	2.5	4.3	6.2	8.6	10.1	13.4
20	13.4	18.9	18.1	14.1	10.6	5.9	3.6	2.4	4.5	6.3	9.0	10.4	13.4
21	14.0	19.3	18.6	14.0	10.4	5.9	3.6	2.5	4.5	6.3	9.1	10.7	14.0
22	14.3	19.6	17.9	13.5	10.1	5.7	3.7	2.4	4.4	6.7	8.8	10.7	14.3
23	14.5	19.7	17.4	13.8	9.9	5.5	3.5	2.7	4.7	6.6	9.3	10.4	14.5
24	14.8	19.4	17.6	14.0	9.8	5.5	3.3	2.8	4.7	6.7	9.1	10.0	14.8
25	15.0	19.7	17.7	13.5	9.4	5.4	3.4	2.9	4.7	6.7	9.0	10.1	15.0
26	14.9	19.6	17.5	13.5	9.4	5.4	3.2	2.9	4.7	6.6	8.8	10.3	14.9
27	15.1	20.0	18.1	13.3	9.4	5.0	3.4	2.9	5.0	6.7	9.0	10.4	15.1
28	15.5	19.8	17.9	13.2	9.1	4.8	3.3	3.0	5.0	6.6	9.1	10.6	15.5
29	15.9	19.6	17.3	13.2	9.0	4.8	3.0	3.1	4.3	6.9	9.3	10.7	15.9
30	16.1	19.2	17.0	13.1	8.9	4.8	3.0	3.2		7.0	9.4	10.8	16.1
31		19.3	17.0		8.6		3.0	3.2		6.8		11.0	
AVG	13.3	18.2	18.6	14.6	11.1	6.4	3.9	2.7	3.8	6.1	8.4	10.0	13.3
T.U.'S				220.7	343.1	41.3							
SUM					605.1								
SIX HUNDRED C UNITS WILL BE AVAILABLE BY NOVEMBER 5													

Table A4.
SNAKE RIVER SUMMER CHINOOK

AVERAGE MINIMUM WATER TEMPERATURE AT SPALDING, IDAHO
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1986

DAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1	10.6	14.6	17.4	15.1	11.9	7.8	4.5	2.2	2.9	4.5	5.7	8.7	10.6
2	10.8	14.6	17.8	14.6	12.1	7.6	4.5	2.0	3.0	4.5	5.7	9.0	10.8
3	11.1	14.5	18.0	14.3	11.8	7.7	4.3	2.0	2.7	4.5	5.8	8.8	11.1
4	11.2	15.0	17.5	14.4	11.5	7.8	4.4	2.4	2.5	4.5	5.8	8.6	11.2
5	11.2	15.2	17.3	14.3	11.4	7.6	4.2	2.3	2.4	4.5	6.2	8.2	11.2
6	11.3	15.1	17.9	14.2	11.5	7.4	4.0	2.1	2.4	4.5	6.4	8.2	11.3
7	11.5	15.0	17.9	14.2	11.3	7.4	4.3	2.2	2.3	4.6	6.2	8.3	11.5
8	11.5	15.1	17.7	13.7	11.2	7.2	4.2	2.4	2.4	4.8	6.4	8.5	11.5
9	11.7	15.1	17.4	13.6	10.8	6.9	4.2	2.2	2.4	4.9	6.6	8.9	11.7
10	11.7	15.0	17.8	13.7	10.9	6.2	4.2	2.1	2.5	4.8	6.6	9.0	11.7
11	12.0	15.0	17.6	13.5	10.9	6.1	4.2	2.0	2.7	4.8	6.8	8.9	12.0
12	12.1	15.2	17.4	13.2	10.6	6.0	3.9	2.0	2.9	4.9	6.9	8.9	12.1
13	11.8	15.4	16.9	13.1	10.5	5.6	3.7	2.3	2.8	5.0	7.0	9.1	11.8
14	11.7	15.4	17.2	13.5	10.5	5.3	3.5	2.4	2.6	5.0	7.1	9.6	11.7
15	11.7	15.7	16.8	13.4	10.5	5.1	3.5	2.5	2.9	5.0	7.4	9.1	11.7
16	12.0	16.1	16.3	13.4	10.3	4.9	3.4	2.3	3.1	5.1	7.5	8.7	12.0
17	12.2	16.2	16.4	13.2	10.2	5.5	3.4	2.3	3.3	5.1	7.3	8.8	12.2
18	12.3	15.8	16.1	13.3	10.0	5.8	3.5	2.3	3.5	5.0	7.4	9.0	12.3
19	12.5	15.6	16.0	13.1	9.7	5.5	3.5	2.0	3.6	5.2	7.4	9.3	12.5
20	12.8	16.3	16.1	12.9	9.9	5.5	3.4	2.0	3.6	5.4	7.5	9.8	12.8
21	12.9	16.5	15.9	13.1	9.5	5.3	3.3	2.1	3.8	5.5	7.1	10.0	12.9
22	13.3	16.6	15.9	12.8	9.2	5.3	3.3	2.1	3.8	5.5	8.0	9.8	13.3
23	13.3	17.0	15.6	12.9	9.2	5.1	3.2	2.3	4.0	5.6	8.1	9.6	13.3
24	13.5	17.0	15.5	12.8	8.9	5.2	3.1	2.5	4.2	5.5	8.2	9.6	13.5
25	13.6	17.0	15.3	12.5	8.8	5.1	2.8	2.6	4.2	5.6	8.0	9.6	13.6
26	13.5	17.3	15.3	12.7	8.8	5.0	2.9	2.5	4.3	5.6	7.7	9.5	13.5
27	13.9	17.5	15.7	12.5	8.6	4.5	3.0	2.4	4.4	5.9	8.0	9.7	13.9
28	14.0	17.2	16.0	12.5	8.4	4.4	3.0	2.8	4.7	5.8	8.0	9.9	14.0
29	14.5	16.9	15.6	12.1	8.5	4.5	2.8	2.8	3.8	5.9	8.2	10.0	14.5
30	14.3	16.8	15.6	12.0	8.3	4.6	2.8	2.7		5.9	8.4	10.1	14.3
31		17.3	15.4		7.9		2.8	2.7		5.9		10.5	
AVG	12.3	15.9	16.6	13.4	10.1	5.9	3.6	2.3	3.2	5.1	7.1	9.2	12.3
T.U.'S				205.2	313.2	85.7							
SUM					604.1								
SIX HUNDRED C UNITS WILL BE AVAILABLE BY NOVEMBER 12													

Table A5.
SNAKE RIVER FALL CHINOOK

AVERAGE MAXIMUM WATER TEMPERATURE AT PECK, IDAHO
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1987

DAY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1	18.8	16.0	12.5	8.5	5.3	3.5	3.1	4.3	5.7	7.9	9.9	15.1	18.8
2	18.9	15.7	12.4	8.2	5.2	3.6	3.2	4.3	5.7	8.1	10.2	14.9	18.9
3	18.9	15.7	12.2	8.2	5.3	3.6	3.1	4.1	5.8	8.0	10.4	15.0	18.9
4	18.6	15.5	12.1	8.3	5.1	3.4	3.0	4.1	6.0	8.0	10.5	15.0	18.6
5	18.8	15.2	12.0	8.0	5.0	3.1	3.1	4.2	6.3	7.8	10.8	15.2	18.8
6	18.9	14.8	11.9	8.0	4.8	3.0	3.0	4.2	6.6	7.6	11.0	15.6	18.9
7	18.8	14.6	11.8	7.8	4.9	3.2	2.9	4.4	6.6	8.0	11.2	15.9	18.8
8	18.8	14.2	11.5	7.6	4.8	3.1	3.0	4.5	6.5	8.2	11.3	16.0	18.8
9	19.2	14.4	11.3	7.2	4.9	3.1	2.8	4.6	6.6	8.4	11.5	15.8	19.2
10	18.7	14.3	11.2	6.9	4.9	3.2	2.8	4.8	6.6	8.3	11.5	16.1	18.7
11	18.6	14.0	11.0	6.6	4.8	3.3	2.8	4.9	6.6	8.3	11.6	16.2	18.6
12	18.5	13.8	10.8	6.4	4.9	3.3	2.6	4.7	6.7	8.3	11.6	16.5	18.5
13	17.9	14.0	10.8	6.1	4.8	3.1	2.7	4.8	6.9	8.9	11.5	16.6	17.9
14	17.8	13.8	10.7	6.0	4.6	3.1	2.7	4.8	7.2	9.1	11.6	16.5	17.8
15	17.7	13.9	10.8	6.1	4.4	2.9	2.6	4.9	7.2	8.7	11.7	17.1	17.7
16	18.0	13.7	10.6	6.5	4.4	2.8	3.0	5.0	7.1	8.3	11.7	15.6	18.0
17	17.6	13.5	10.5	6.6	4.1	2.8	3.2	4.9	7.3	8.3	11.8	16.8	17.6
18	17.3	13.4	10.5	6.5	4.1	2.8	3.2	4.9	7.3	8.9	11.9	16.6	17.3
19	17.4	13.4	10.3	6.4	4.0	2.8	3.2	4.9	7.2	9.5	12.1	17.1	17.4
20	17.2	13.4	10.3	6.4	4.0	2.8	3.3	5.1	7.4	9.8	12.3	17.3	17.2
21	16.8	13.3	10.1	6.1	3.9	2.9	3.4	5.0	7.4	9.8	12.5	17.6	16.8
22	16.5	13.2	9.8	6.1	4.0	2.9	3.5	5.4	7.8	9.7	12.8	18.0	16.5
23	16.2	13.1	9.5	5.9	3.8	2.9	3.6	5.3	8.3	9.4	13.1	18.1	16.2
24	16.3	12.9	9.3	5.9	3.7	3.1	3.7	5.5	8.3	9.1	13.3	18.1	16.3
25	16.2	12.8	9.3	5.9	3.5	2.9	3.9	5.5	7.8	9.1	13.7	18.2	16.2
26	16.8	12.8	9.1	5.6	3.5	2.8	3.9	5.5	7.8	9.4	13.8	18.2	16.8
27	16.9	12.8	9.0	5.1	3.8	3.1	4.2	5.6	7.8	9.4	14.0	18.3	16.9
28	16.5	12.6	8.9	5.3	3.8	3.2	4.1	5.5	7.8	9.4	14.6	18.3	16.5
29	16.0	12.7	8.6	5.2	3.9	3.1	4.0	5.6	7.9	9.7	14.9	18.4	16.0
30	16.0	12.6	8.7	5.1	3.7	3.0		5.8	7.8	9.8	15.0	18.4	16.0
31	16.1		8.4		3.7	3.1		5.6		9.9	15.0	18.1	16.1
AVG	17.6	13.9	10.5	6.6	4.4	3.1	3.2	4.9	7.1	8.8	12.2	16.8	17.6
T.U.'S				94.7	135.3	95.4	93.7	152.6	211.7	215.4			
SUM								998.7					
ONE THOUSAND C UNITS WOULD BE AVAILABLE BY MAY 25													

Table A6.
SNAKE RIVER FALL CHINOOK

AVERAGE MINIMUM WATER TEMPERATURE AT PECK, IDAHO
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1987

DAY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1	16.4	14.2	11.5	7.7	4.6	3.1	2.5	3.7	5.0	7.0	8.9	13.6	16.4
2	16.9	14.0	11.5	7.7	4.5	3.1	2.4	3.6	4.9	7.0	9.2	13.4	16.9
3	16.9	14.0	11.4	7.7	4.5	3.2	2.2	3.7	5.0	7.2	9.3	13.6	16.9
4	16.6	14.0	11.3	7.8	4.6	2.7	2.2	3.6	5.2	7.0	9.5	13.8	16.6
5	16.8	13.6	11.0	7.6	4.4	2.8	2.2	3.8	5.4	6.8	9.4	13.8	16.8
6	16.9	13.1	11.0	7.5	4.5	2.6	2.4	3.8	5.8	6.8	9.9	14.0	16.9
7	16.4	12.9	10.9	7.3	4.5	2.7	2.2	3.9	5.8	6.9	10.1	14.2	16.4
8	16.5	13.0	10.5	7.2	4.3	2.9	2.0	4.0	5.7	7.4	10.3	14.5	16.5
9	16.9	12.9	10.5	6.6	4.3	2.6	2.0	4.2	5.8	7.4	10.4	14.3	16.9
10	16.8	13.0	10.5	6.3	4.1	2.7	2.0	4.3	5.8	7.4	10.4	14.2	16.8
11	16.4	12.8	10.3	6.1	4.0	2.6	2.1	4.3	5.8	7.2	10.5	14.4	16.4
12	16.4	12.7	10.1	5.8	3.9	2.7	2.2	4.3	5.8	7.4	10.7	14.4	16.4
13	16.0	12.7	9.9	5.6	3.9	2.5	2.2	4.4	5.9	7.6	10.5	14.3	16.0
14	16.0	12.6	9.8	5.5	3.8	2.3	2.0	4.3	6.1	8.1	10.6	14.5	16.0
15	15.6	12.5	9.8	5.6	3.6	2.0	2.1	4.3	6.2	7.8	10.7	15.1	15.6
16	15.5	12.6	9.8	5.4	3.6	2.0	2.4	4.4	6.4	7.3	10.8	15.3	15.5
17	15.5	12.5	9.7	6.0	3.6	2.3	2.6	4.4	6.3	7.2	11.0	15.2	15.5
18	15.0	12.5	9.6	5.9	3.5	2.1	2.8	4.4	6.3	7.5	11.0	14.9	15.0
19	15.1	12.4	9.6	5.7	3.6	2.2	2.8	4.4	6.4	8.1	10.9	15.2	15.1
20	14.7	12.5	9.7	5.6	3.5	2.3	2.9	4.5	6.4	8.7	11.1	15.4	14.7
21	14.9	12.3	9.5	5.7	3.6	2.4	2.8	4.6	6.4	8.7	11.5	15.5	14.9
22	14.6	12.2	9.1	5.6	3.4	2.2	2.9	4.7	6.7	8.3	11.6	16.1	14.6
23	14.5	12.2	8.8	5.7	3.3	2.4	3.0	4.9	7.1	8.0	12.0	16.1	14.5
24	14.5	12.0	8.6	5.4	3.2	2.4	3.0	4.9	7.3	8.1	12.2	16.5	14.5
25	14.2	11.8	8.6	5.3	3.0	2.4	3.3	5.0	6.8	8.2	12.2	16.4	14.2
26	14.6	11.8	8.5	4.6	3.0	2.5	3.5	5.1	6.7	8.3	12.3	16.6	14.6
27	15.3	11.9	8.3	4.4	3.1	2.6	3.5	5.0	6.7	8.3	12.5	16.2	15.3
28	14.9	12.0	8.1	4.6	3.3	2.8	3.6	4.9	6.9	8.4	13.0	15.9	14.9
29	14.6	11.8	8.1	4.7	3.3	2.7	3.5	4.8	6.8	8.6	13.3	15.8	14.6
30	14.4	11.8	8.0	4.8	3.4	2.6		4.8	6.8	8.8	13.4	16.0	14.4
31	14.5		7.9		3.4	2.6		4.9		8.8		16.3	14.5
AVG	15.6	12.7	9.7	6.0	3.8	2.5	2.6	4.4	6.1	7.8	11.0	15.0	15.6
T.U.'S				84.9	117.4	79.0	75.2	125.9	177.4	222.8	118.5		
SUM								1001					
ONE THOUSAND C UNITS WOULD BE AVAILABLE BY JUNE 12													

Table A7.
SNAKE RIVER FALL CHINOOK

AVERAGE MAXIMUM WATER TEMPERATURE AT SPALDING, IDAHO
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1987

DAY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1	19.6	16.7	13.2	8.3	4.9	2.6	3.3	5.2	7.1	9.5	11.2	16.3	19.6
2	19.6	16.4	13.2	8.4	4.9	2.3	3.3	5.4	6.8	9.0	11.5	16.0	19.6
3	19.9	16.1	13.1	8.3	4.8	2.7	3.5	5.1	7.0	9.5	11.4	16.1	19.9
4	19.6	16.3	12.9	8.3	4.7	2.8	3.1	5.3	7.2	9.2	11.9	16.2	19.6
5	19.7	16.3	12.8	8.0	4.5	2.5	2.9	5.3	7.5	9.1	12.0	16.6	19.7
6	19.7	16.0	12.7	7.9	4.6	2.5	2.8	5.5	7.6	8.9	12.0	16.8	19.7
7	19.9	15.8	12.6	8.0	4.5	2.4	3.0	5.2	7.6	9.1	12.2	16.7	19.9
8	19.4	15.5	12.5	7.8	4.5	2.5	3.0	5.7	7.5	9.5	12.3	16.9	19.4
9	19.6	14.8	12.0	7.4	4.3	2.5	2.9	5.6	7.9	9.8	12.3	17.3	19.6
10	19.9	14.8	11.9	7.3	4.4	2.3	2.9	5.7	8.1	9.9	12.4	17.2	19.9
11	19.8	14.6	11.7	6.7	4.5	2.3	3.1	5.9	8.3	9.8	12.7	17.4	19.8
12	19.3	14.4	11.4	6.5	4.4	2.6	3.4	5.7	8.3	9.8	12.6	17.5	19.3
13	18.9	14.5	11.4	6.2	4.1	2.7	3.5	5.8	8.5	10.3	12.3	18.0	18.9
14	18.9	14.7	11.6	5.8	3.9	2.9	3.4	6.1	8.8	10.5	12.5	18.1	18.9
15	18.8	14.6	11.5	5.5	3.7	2.6	3.6	6.1	8.6	10.0	12.6	18.4	18.8
16	18.6	14.5	11.4	5.9	3.8	2.7	3.8	6.1	8.7	9.7	12.8	18.5	18.6
17	18.5	14.3	11.0	6.2	3.8	2.5	3.9	6.0	8.9	9.6	12.9	18.8	18.5
18	18.3	14.1	10.8	6.2	3.8	2.9	4.2	6.0	8.7	9.7	13.2	18.4	18.3
19	17.9	14.0	10.8	6.0	3.7	2.5	4.3	6.2	8.6	10.1	13.4	18.2	17.9
20	18.1	14.1	10.6	5.9	3.6	2.4	4.5	6.3	9.0	10.4	13.4	18.9	18.1
21	18.6	14.0	10.4	5.9	3.6	2.5	4.5	6.3	9.1	10.7	14.0	19.3	18.6
22	17.9	13.5	10.1	5.7	3.7	2.4	4.4	6.7	8.8	10.7	14.3	19.6	17.9
23	17.4	13.8	9.9	5.5	3.5	2.7	4.7	6.6	9.3	10.4	14.5	19.7	17.4
24	17.6	14.0	9.8	5.5	3.3	2.8	4.7	6.7	9.1	10.0	14.8	19.4	17.6
25	17.7	13.5	9.4	5.4	3.4	2.9	4.7	6.7	9.0	10.1	15.0	19.7	17.7
26	17.5	13.5	9.4	5.4	3.2	2.9	4.7	6.6	8.8	10.3	14.9	19.6	17.5
27	18.1	13.3	9.4	5.0	3.4	2.9	5.0	6.7	9.0	10.4	15.1	20.0	18.1
28	17.9	13.2	9.1	4.8	3.3	3.0	5.0	6.6	9.1	10.6	15.5	19.8	17.9
29	17.3	13.2	9.0	4.8	3.0	3.1	4.3	6.9	9.3	10.7	15.9	19.6	17.3
30	17.0	13.1	8.9	4.8	3.0	3.2		7.0	9.4	10.8	16.1	19.2	17.0
31	17.0		8.6		3.0	3.2		6.8		11.0		19.3	17.0
AVG	18.6	14.6	11.1	6.4	3.9	2.7	3.8	6.1	8.4	10.0	13.3	18.2	18.6
T.U.'S				88.3	121.7	82.5	110.3	187.7	251.6	163.0			
SUM							1005						
ONE THOUSAND TEMPERATURE UNITS WILL BE AVAILABLE BY MAY 17													

Table A8.
SNAKE RIVER FALL CHINOOK

AVERAGE MINIMUM WATER TEMPERATURE AT SPALDING, IDAHO
CALCULATED USING USGS DATA FROM OCTOBER 1972 - SEPTEMBER 1987

DAY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1	17.4	15.1	11.9	7.8	4.5	2.2	2.9	4.5	5.7	8.7	10.6	14.6	17.4
2	17.8	14.6	12.1	7.6	4.5	2.0	3.0	4.5	5.7	9.0	10.8	14.6	17.8
3	18.0	14.3	11.8	7.7	4.3	2.0	2.7	4.5	5.8	8.8	11.1	14.5	18.0
4	17.5	14.4	11.5	7.8	4.4	2.4	2.5	4.5	5.8	8.6	11.2	15.0	17.5
5	17.3	14.3	11.4	7.6	4.2	2.3	2.4	4.5	6.2	8.2	11.2	15.2	17.3
6	17.9	14.2	11.5	7.4	4.0	2.1	2.4	4.5	6.4	8.2	11.3	15.1	17.9
7	17.9	14.2	11.3	7.4	4.3	2.2	2.3	4.6	6.2	8.3	11.5	15.0	17.9
8	17.7	13.7	11.2	7.2	4.2	2.4	2.4	4.8	6.4	8.5	11.5	15.1	17.7
9	17.4	13.6	10.8	6.9	4.2	2.2	2.4	4.9	6.6	8.9	11.7	15.1	17.4
10	17.8	13.7	10.9	6.2	4.2	2.1	2.5	4.8	6.6	9.0	11.7	15.0	17.8
11	17.6	13.5	10.9	6.1	4.2	2.0	2.7	4.8	6.8	8.9	12.0	15.0	17.6
12	17.4	13.2	10.6	6.0	3.9	2.0	2.9	4.9	6.9	8.9	12.1	15.2	17.4
13	16.9	13.1	10.5	5.6	3.7	2.3	2.8	5.0	7.0	9.1	11.8	15.4	16.9
14	17.2	13.5	10.5	5.3	3.5	2.4	2.6	5.0	7.1	9.6	11.7	15.4	17.2
15	16.8	13.4	10.5	5.1	3.5	2.5	2.9	5.0	7.4	9.1	11.7	15.7	16.8
16	16.3	13.4	10.3	4.9	3.4	2.3	3.1	5.1	7.5	8.7	12.0	16.1	16.3
17	16.4	13.2	10.2	5.5	3.4	2.3	3.3	5.1	7.3	8.8	12.2	16.2	16.4
18	16.1	13.3	10.0	5.8	3.5	2.3	3.5	5.0	7.4	9.0	12.3	15.8	16.1
19	16.0	13.1	9.7	5.5	3.5	2.0	3.6	5.2	7.4	9.3	12.5	15.6	16.0
20	16.1	12.9	9.9	5.5	3.4	2.0	3.6	5.4	7.5	9.8	12.8	16.3	16.1
21	15.9	13.1	9.5	5.3	3.3	2.1	3.8	5.5	7.1	10.0	12.9	16.5	15.9
22	15.9	12.8	9.2	5.3	3.3	2.1	3.8	5.5	8.0	9.8	13.3	16.6	15.9
23	15.6	12.9	9.2	5.1	3.2	2.3	4.0	5.6	8.1	9.6	13.3	17.0	15.6
24	15.5	12.8	8.9	5.2	3.1	2.5	4.2	5.5	8.2	9.6	13.5	17.0	15.5
25	15.3	12.5	8.8	5.1	2.8	2.6	4.2	5.6	8.0	9.6	13.6	17.0	15.3
26	15.3	12.7	8.8	5.0	2.9	2.5	4.3	5.6	7.7	9.5	13.5	17.3	15.3
27	15.7	12.5	8.6	4.5	3.0	2.4	4.4	5.9	8.0	9.7	13.9	17.5	15.7
28	16.0	12.5	8.4	4.4	3.0	2.8	4.7	5.8	8.0	9.9	14.0	17.2	16.0
29	15.6	12.1	8.5	4.5	2.8	2.8	3.8	5.9	8.2	10.0	14.5	16.9	15.6
30	15.6	12.0	8.3	4.6	2.8	2.7		5.9	8.4	10.1	14.3	16.8	15.6
31	15.4		7.9		2.8	2.7		5.9		10.5		17.3	15.4
AVG	16.6	13.4	10.1	5.9	3.6	2.3	3.2	5.1	7.1	9.2	12.3	15.9	16.6
T.U.'S				81.4	111.4	71.2	93.7	159.3	213.3	275.5			
SUM							1006						

ONE THOUSAND TEMPERATURE UNITS WILL BE AVAILABLE MAY 30

APPENDIX B

Table B1. Maximum July water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum July water temperatures recorded by the United States Geological Survey at Peck, Idaho 1973 - 1987.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	19.5	13.0
1974	⁽¹⁾ 19.5	19.0
1975	⁽¹⁾ 20.5	19.0
1976	⁽²⁾ 21.5	17.5
1977	⁽¹⁾ 20.0	14.0
1978	⁽¹⁾ 20.0	16.5, 18.0
1979	⁽²⁾ 21.5	15.5, 19.5
1980	⁽²⁾ 21.0	19.0, 18.5
1981	⁽²⁾ 19.5	16.5
1982	⁽¹⁾ 19.5	17.5, 18.5, 17.5
1983	⁽³⁾ 18.5	17.0
1984	⁽¹⁾ 20.0	18.5
1985	⁽¹⁾ <u> </u>	----
1986	18.0	16.0, 16.5, 16.5
1987	⁽³⁾ 22.5	20.5
	(1)	

Table B2. Maximum August water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum August water temperature recorded by the United States Geological Survey at Peck, Idaho 1973-1987.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	16.5 (5)	15.5, 15.5, 16.0, 16.0, 15.5
1974	21.5 (1)	20.5
1975	20.5 (2)	19.0, 19.5
1976	21.0 (1)	20.0
1977	20.0 (1)	15.5
1978	22.0 (1)	19.0
1979	19.5 (1)	14.0
1980	19.5 (1)	16.0
1981	21.0 (1)	16.5
1982	20.0 (1)	18.0
1983	23.0 (1)	20.0
1984	21.5 (1)	19.0
1985	---- (1)	----
1986	19.0 (3)	16.5, 16.5, 16.5
1987	20.5 (2)	17.0, 17.5

Table B3. Maximum September water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum September water temperatures recorded by the United States Geological Survey at Peck, Idaho 1973-1987.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	14.0	13.0
1974	⁽¹⁾ 19.5	18.0
1975	⁽¹⁾ 16.0 (9)	15.0, 15.5, 15.0, 14.5, 14.5, 14.5, 14.5, 14.5, 14.5,
1976	20.0	16.0
1977	⁽¹⁾ 17.0	12.5, 15.5
1978	⁽²⁾ 19.5	17.5
1979	⁽¹⁾ 16.0	12.5, 12.5
1980	⁽²⁾ 15.0	13.5
1981	⁽¹⁾ 15.5	11.5
1982	⁽¹⁾ 17.5	15.0, 14.5
1983	⁽²⁾ 18.0	16.0
1984	⁽¹⁾ 16.0	14.0
1985	⁽¹⁾ ----	----
1986	14.0	13.0, 13.5
1987	⁽²⁾ ----	----

Table B4. Maximum October water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum October water temperatures recorded by the United States Geological Survey at Peck, Idaho 1972-1986.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1972	10.0 (12)	9.5, 9.5, 9.5, 9.5, 9.5, 9.5, 9.5, 9.5, 10.0, 10.0, 10.0, 9.5
1973	14.5 (2)	14.0, 13.5
1974	14.5 (1)	13.5
1975	14.5 (2)	13.0, 13.0
1976	15.5 (2)	14.0, 14.5
1977	12.0 (2)	11.0, 11.0
1978	14.0 (2)	13.0, 12.5
1979	12.5 (1)	11.0
1980	12.5 (2)	11.5, 11.0
1981	12.5 (1)	11.0
1982	11.5 (3)	10.5, 10.5, 11.0
1983	12.5 (2)	11.0, 11.5
1984	_____	_____
1985	10.0 (2)	10.0, 9.5
1986	12.0 (5)	11.0, 11.0, 11.0 11.0, 11.0

Table B5. Minimum November water temperatures, consecutive days of minimum temperature occurrence, and corresponding maximum November water temperatures recorded by the United States Geological Survey at Peck, Idaho 1972-1986.

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1972	4.5	5.0
1973	(1) 3.5	4.0, 4.0, 4.0
1974	(6) 5.5	4.0, 4.0, 4.5 6.0, 5.5
1975	(2) 2.0	2.5
1976	(1) 4.5	6.5
1977	(1) 0.0	0.5, 4.0
1978	(2) 2.5	3.5
1979	(1) 5.0	6.6, 6.5
1980	(2) 3.0	6.0, 7.0, 7.0
1981	(3) 6.0	6.5, 7.0, 6.5,
1982	(5) 3.5	6.0, 6.5 6.5
1983	(1) 6.5	7.0, 6.6
1984	(2) ---	---
1985	3.5	4.0, 4.0
1986	(4) 2.5	4.0, 3.5 4.5, 4.5
	(2)	

Table B6. Minimum December water temperatures, consecutive days of minimum temperature occurrence, and corresponding maximum December water temperatures recorded by United States Geological Survey at Peck, Idaho 1972-1986.

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1972	0.5 (2)	1.0, 1.0
1973	3.0 (2)	5.0, 5.5
1974	4.0 (5)	4.5, 4.5, 4.5 4.0, 4.5
1975	0.5 (1)	4.0
1976	3.0 (5)	4.5, 3.0, 4.5, 4.0, 4.0
1977	0.5 (1)	2.5
1978	1.5 (1)	4.0
1979	2.0 (1)	3.0
1980	1.5 (1)	5.5
1981	1.5 (4)	2.0, 1.5 1.5, 2.5
1982	2.0 (3)	2.5, 2.0, 4.0
1983	3.5 (6)	4.5, 4.5, 4.5 4.0, 4.0, 4.0
1984	---	---
1985	1.5 (3)	3.0, 1.5, 3.0
1986	1.5 (1)	2.0

Table B7. Minimum January water temperatures, consecutive days of minimum temperature occurrence, and corresponding maximum January water temperature recorded by the United States Geological Survey at Peck, Idaho.

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1973	1.0 (2)	1.5, 1.5
1974	0.5 (3)	3.0, 0.5, 1.0
1975	0.5 (2)	3.5, 1.5
1976	2.5 (3)	3.0, 3.0, 3.0
1977	1.0 (1)	2.0
1978	0.5 (1)	2.5
1979	1.0 (3)	1.5, 1.0, 2.5
1980	0.0 (1)	3.0
1981	1.0 (4)	3.0, 1.0, 1.0, 1.5
1982	0.5 (1)	3.0
1983	2.0 (4)	3.0, 2.5 2.0, 3.0
1984	0.5 (3)	2.0, 0.5, 1.0
1985	---	---
1986	1.5 (7)	2.0, 1.5, 1.5, 1.5 2.0, 2.0, 2.0
1987	0.0 (1)	0.5

Table B8. Minimum February water temperatures, consecutive days of minimum temperature occurrence, and corresponding minimum February water temperatures recorded by the United States Geological Survey at Peck, Idaho 1973-1987.

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1973	1.0 (5)	1.5, 1.5, 1.5, 1.0, 1.5
1974	3.5 (8)	4.0, 4.0, 4.0, 4.0, 3.5, 3.5, 4.0, 4.0
1975	3.0 (1)	4.0
1976	0.5 (1)	2.0
1977	1.5 (2)	2.5, 3.5
1978	2.5 (2)	3.0, 3.0
1979	0.0 (4)	1.0, 0.0, 0.0, 0.5
1980	1.0 (8)	3.0, 2.5, 2.5, 2.5, 2.5, 2.5, 1.5, 2.5
1981	0.5 (5)	3.0, 1.0, 1.0, 1.0, 1.0
1982	0.0 (2)	2.5, 1.0
1983	0.5 (1)	1.5
1984	2.0 (7)	2.0, 2.0, 2.5, 2.5, 2.5, 2.0, 2.5
1986	1.0 (2)	1.5, 1.5
1987	0.0 (2)	1.0, 1.0

Table B9. Maximum July water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum July water temperatures recorded by the United States Geological Survey at Spalding, Idaho 1973-1986.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	23.0	17.0
1974	⁽¹⁾ 19.0	17.0, 18.0
1975	⁽²⁾ 22.0	19.5
1976	⁽¹⁾ 20.5	18.5, 19.0, 17.0, 16.5
1977	⁽⁴⁾ 21.0	15.0
1978	⁽¹⁾ 22.0	20.5
1979	⁽¹⁾ 21.0	18.0
1980	⁽¹⁾ 22.0	17.0, 18.5, 18.5, 19.5, 20.0
1981	⁽⁵⁾ 20.5	16.5
1982	⁽¹⁾ 20.0	18.5
1983	⁽¹⁾ 19.5	18.0, 18.5, 19.0
1984	⁽³⁾ 23.5	23.0, 17.0
1985	⁽²⁾ 23.0	20.5
1986	⁽¹⁾ 20.0	18.0, 18.5
	⁽²⁾	

Table B10. Maximum August water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum August water temperatures recorded by the United States Geological Survey at Spalding, Idaho

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	21.0	18.0, 19.5, 19.5
1974	⁽³⁾ 20.0	16.5
1975	⁽¹⁾ 20.5	18.5
1976	⁽¹⁾ 21.0	20.5, 19.0
1977	⁽²⁾ 22.0	18.5
1978	⁽¹⁾ 23.5	21.5
1979	⁽¹⁾ 20.0	16.5
1980	⁽¹⁾ 19.5	18.0
1981	⁽¹⁾ 21.5	19.0
1982	⁽¹⁾ 20.5	18.5, 19.0
1983	⁽²⁾ 20.0	19.0
1984	⁽¹⁾ 24.0	21.0
1985	⁽¹⁾ 20.0	17.0
1986	⁽¹⁾ 21.5 ⁽³⁾	18.5, 19.5, 20.0

Table B11. Maximum September water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum September water temperatures recorded by the United States Geological Survey at Spalding, 1973-1986.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	17.0	16.0, 15.5
1974	⁽²⁾ 19.0	17.0, 16.0
1975	⁽²⁾ 15.5	14.0, 14.0
1976	⁽²⁾ 19.0	16.0
1977	⁽¹⁾ 20.0	17.0
1978	⁽¹⁾ 20.0	16.5, 17.0
1979	⁽²⁾ 15.5	14.0, 13.5
1980	⁽²⁾ 16.0	13.5
1981	⁽¹⁾ 16.0	15.0
1982	⁽¹⁾ 19.0	16.0, 16.0
1983	⁽²⁾ 19.0	17.0, 17.0
1984	⁽²⁾ ---	----
1985	17.0	15.5, 16.0
1986	⁽²⁾ 17.0 ⁽¹⁾	15.0

Table B12. Maximum October water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum October water temperatures recorded by the United States Geological Survey at Spalding, Idaho 1972-1985.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1972	13.5 (4)	11.5, 12.0, 11.0, 11.0
1973	16.5 (1)	16.0
1974	13.5 (2)	13.0, 13.0
1975	----	----
1976	15.0 (1)	14.5
1977	14.0 (1)	13.0
1978	14.0 (2)	13.0, 12.0
1979	14.0 (2)	12.0, 12.0
1980	13.0 (8)	11.5, 11.5, 11.5, 11.5 11.5, 11.0, 11.0, 11.5
1981	11.5 (2)	10.0, 11.0
1982	13.0 (4)	11.5, 12.0, 12.0, 11.5
1983	14.0 (2)	13.0, 13.0
1984	14.0 (4)	11.5, 12.0, 13.0, 12.0
1985	11.0 (1)	9.5

Table B13. Minimum November water temperatures, consecutive days of minimum temperature occurrence, and corresponding maximum November water temperatures recorded by the United States Geological Survey at Spalding, Idaho 1972-1985.

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1972	4.5	5.5, 4.5, 5.0
1973	(3) 5.0	5.5, 5.5, 5.0
1974	(6) 4.5	6.0, 5.5, 6.0
1975	(1) 0.5	5.0
1976	(1) 4.5	1.0
1977	(2) 1.0	5.5, 5.5
1978	(2) 0.5	3.5, 3.0
1979	(1) 4.5	1.5
1980	(3) 5.5	5.0, 4.5, 5.0
1981	(1) 5.5	8.5
1982	(1) 4.5	6.0
1983	(2) 8.5	5.0, 5.5
1984	(3) 5.5	9.0, 8.5, 8.5
1985	(1) 2.0	6.0
	(2)	2.0, 4.0

Table B14. Minimum December water temperatures, consecutive days of minimum temperature occurrence, and corresponding minimum December water temperature recorded by the United States Geological Survey at Spalding, Idaho

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1972	0.5	2.0, 1.0, 1.0
1973	⁽³⁾ 3.5	4.0
1974	⁽¹⁾ 1.0	2.0
1975	⁽¹⁾ 1.0	4.0
1976	⁽¹⁾ 1.0	2.0, 1.5, 1.0, 1.5
1977	⁽⁴⁾ 3.0	4.0, 3.5, 3.5
1978	⁽³⁾ 1.5	2.0
1979	⁽¹⁾ 2.0	3.0, 2.0
1980	⁽²⁾ 4.0	4.5, 4.0, 4.0, 4.0, 4.5, 4.0, 4.0, 4.5
1981	⁽⁸⁾ 1.5	2.0, 1.5, 1.5, 1.5
1982	⁽⁴⁾ 2.0	3.0, 2.0, 3.0
1983	⁽³⁾ ---	---
1984	---	---
1985	1.0 (1)	2.0

Table B15. Minimum January water temperatures, consecutive days of minimum temperature occurrence, and corresponding maximum January water temperatures recorded by the United States Geological Survey at Spalding, Idaho 1973-1986.

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1973	0.0 (8)	1.0, 0.5, 0.5, 0.0, 0.0, 0.0, 0.0, 1.0
1974	2.0	3.0, 2.0, 3.0
1975	⁽³⁾ 1.0	2.0
1976	⁽¹⁾ 2.0	2.5, 2.0, 2.0, 2.5
1977	⁽⁴⁾ 0.0	3.0, 0.5
1978	⁽²⁾ 2.0	3.0
1979	⁽¹⁾ 0.0	1.0, 0.5, 0.0, 0.5, 0.5, 0.5
1980	⁽¹¹⁾ 0.0	0.5, 1.0, 0.5, 0.0, 0.5 2.0, 1.5
1981	⁽²⁾ 3.5	4.0
1982	⁽¹⁾ 1.5	1.5, 1.5, 1.5, 1.5,
1983	⁽⁷⁾ 1.5	1.5, 1.5, 2.0 2.0, 2.0
1984	⁽²⁾ 0.5	1.0, 0.5, 1.5
1985	⁽³⁾ 3.0	3.0, 3.0, 3.0, 3.0,
1986	⁽⁸⁾ 0.5	3.0, 3.5, 3.0, 3.0 1.0, 1.0
	⁽²⁾	

Table B16. Minimum February water temperatures, consecutive days of minimum temperature occurrence, and corresponding maximum February water temperatures recorded by the United States Geological Survey at Spalding, Idaho 1973-1986.

Year	Minimum temperature (°C) (consecutive days of occurrence)	Corresponding maximum temperature
1973	0.0	2.0
1974	(1) 3.5	4.0
1975	(1) 1.5	1.5
1976	(1) 1.5	2.0, 1.5, 2.0
1977	(3) 2.0	4.5
1978	(1) 3.0	3.5, 3.0, 3.0, 3.5, 3.5
1979	(5) 0.5	1.0
1980	(1) 1.5	2.0, 3.0
1981	(2) 1.5	2.0, 1.5, 1.5,
1982	(6) 1.0	1.5, 1.5, 2.0 2.0
1983	(1) 2.0	3.0, 3.0
1984	(2) 1.5	1.5, 1.5, 1.5, 1.5,
1985	(7) 2.0	1.5, 1.5, 2.0 3.0, 3.0
1986	(2) 3.5	4.5
	(1)	

Table B17. Maximum May water temperatures, consecutive days of minimum temperature occurrence, and corresponding minimum May water temperatures recorded by the United States Geological Survey at Peck, Idaho 1973-1986.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	10.0	9.5, 10.0, 10.0
1974	⁽³⁾ 10.5	9.0, 9.0
1975	⁽²⁾ 8.5	7.5, 8.0, 8.0, 7.5, 7.5
1976	⁽⁵⁾ 10.0	8.0
1977	⁽¹⁾ 11.5	10.0, 9.5
1978	⁽²⁾ 10.0	8.5, 8.5
1979	⁽²⁾ 9.5	8.0, 8.5, 8.5
1980	⁽³⁾ 11.5	10.0
1981	⁽¹⁾ 11.0	9.5, 10.0
1982	⁽²⁾ 9.0	7.0
1983	⁽¹⁾ 11.5	10.5, 10.0
1984	⁽²⁾ 14.5	8.0
1985	⁽¹⁾ _____	_____
1986	10.5	9.0, 10.0
1987	⁽²⁾ 14.5	13.5, 14.0, 14.0
	⁽³⁾	

Table B18. Maximum June water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum June water temperatures recorded by the United States Geological Survey at Peck, Idaho 1973-1987.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	16.0	14.5, 15.0
1974	14.5 ⁽²⁾	14.0
1975	11.0 ⁽¹⁾	9.5
1976	14.5 ⁽¹⁾	12.5
1977	20.0 ⁽¹⁾	16.5, 16.5
1978	13.5 ⁽²⁾	12.0, 12.5
1979	17.0 ⁽²⁾	14.0
1980	15.5 ⁽¹⁾	13.0
1981	15.5 ⁽¹⁾	12.5
1982	12.0 ⁽¹⁾	10.5
1983	15.0 ⁽¹⁾	13.5
1984	13.5 ⁽¹⁾	12.0, 12.5
1985	--- ⁽²⁾	----
1986	19.0	16.0
1987	23.0 ⁽¹⁾ (1)	20.5

Table B19. Maximum May water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum May water temperatures recorded by the United States Geological Survey at Spalding, Idaho 1973-1986.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	16.0	14.0
1974	⁽¹⁾ 11.0	9.5, 10.0
1975	⁽²⁾ 12.0	10.5
1976	⁽¹⁾ 11.5	10.0, 10.5
1977	⁽²⁾ 13.5	11.5
1978	⁽¹⁾ 10.0	9.5, 9.5
1979	⁽²⁾ 13.5	13.0
1980	⁽¹⁾ 10.5	10.0, 10.5, 9.5
1981	⁽³⁾ 13.0	12.0, 12.0
1982	⁽²⁾ 11.5	11.0
1983	⁽¹⁾ 11.5	11.0, 11.0, 11.5,
1984	⁽⁶⁾ 11.0	11.5, 11.5, 10.5 9.5, 10.5
1985	⁽²⁾ 10.5	9.5, 9.5
1986	⁽²⁾ 11.0 ⁽³⁾	10.0, 10.0, 10.5

Table B20. Maximum June water temperatures, consecutive days of maximum temperature occurrence, and corresponding minimum June water temperatures recorded by the United States Geological Survey at Spalding, Idaho 1973-1986.

Year	Maximum temperature (°C) (consecutive days of occurrence)	Corresponding minimum temperature
1973	20.5	19.0, 19.5
1974	⁽²⁾ 13.0	12.0
1975	⁽¹⁾ 12.0	11.5, 11.5
1976	⁽²⁾ 14.0	12.0, 12.5
1977	⁽²⁾ 20.5	17.0, 17.0, 19.0
1978	⁽³⁾ 15.5	15.0, 14.5
1979	⁽²⁾ 17.0	14.5, 14.5, 14.5, 14.5
1980	⁽⁴⁾ 16.0	13.0
1981	⁽¹⁾ 18.0	15.5
1982	⁽¹⁾ 12.0	11.0
1983	⁽¹⁾ 19.0	16.5
1984	⁽¹⁾ 15.0	15.0, 14.0
1985	⁽²⁾ 19.0	16.0
1986	⁽¹⁾ 19.5 (1)	18.5

APPENDIX C

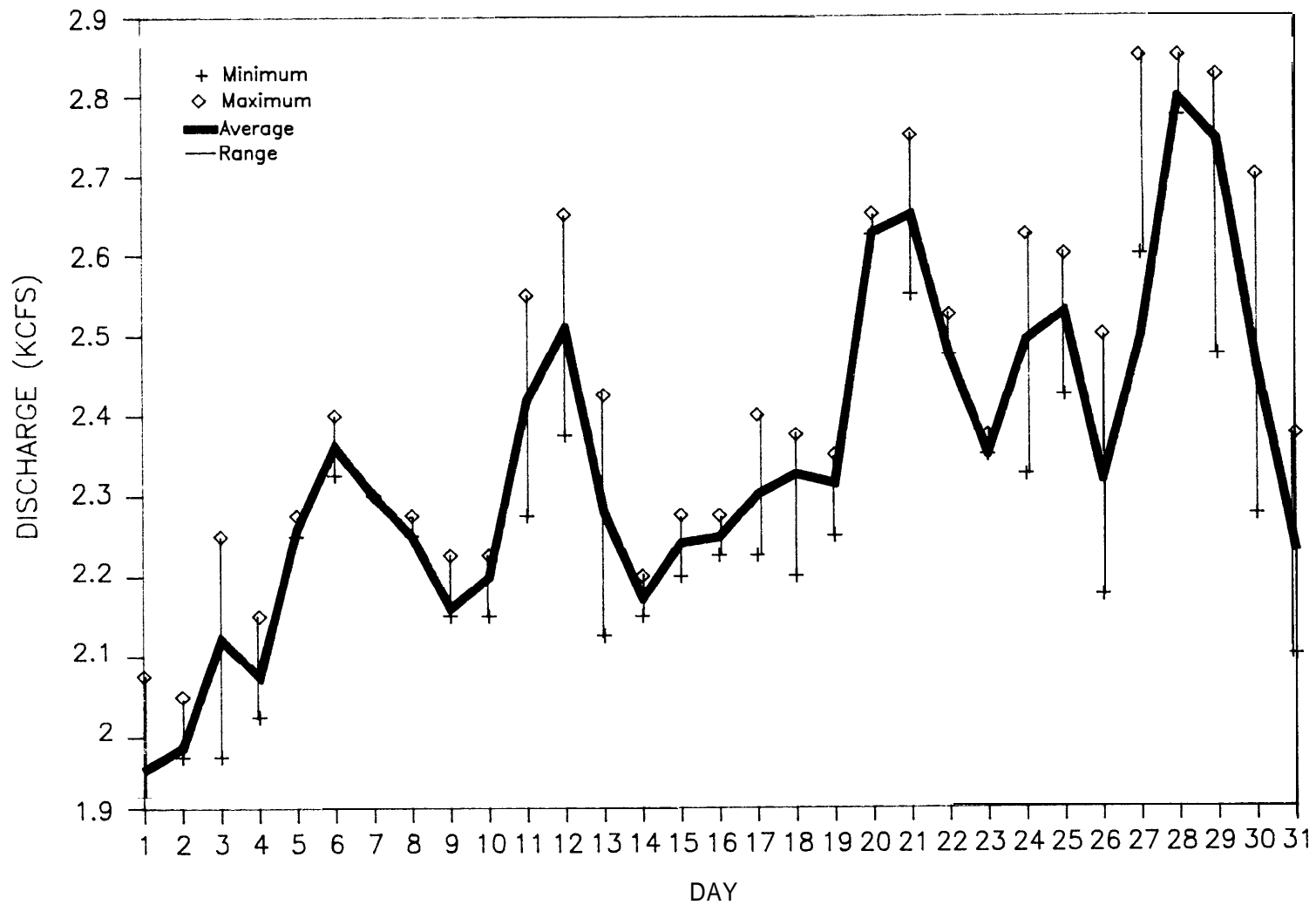


Figure C1. Average, minimum and maximum discharge from Dworshak Dam recorded by United States Army Corps of Engineers on the Northfork Clearwater River, October 1982 - 1985.

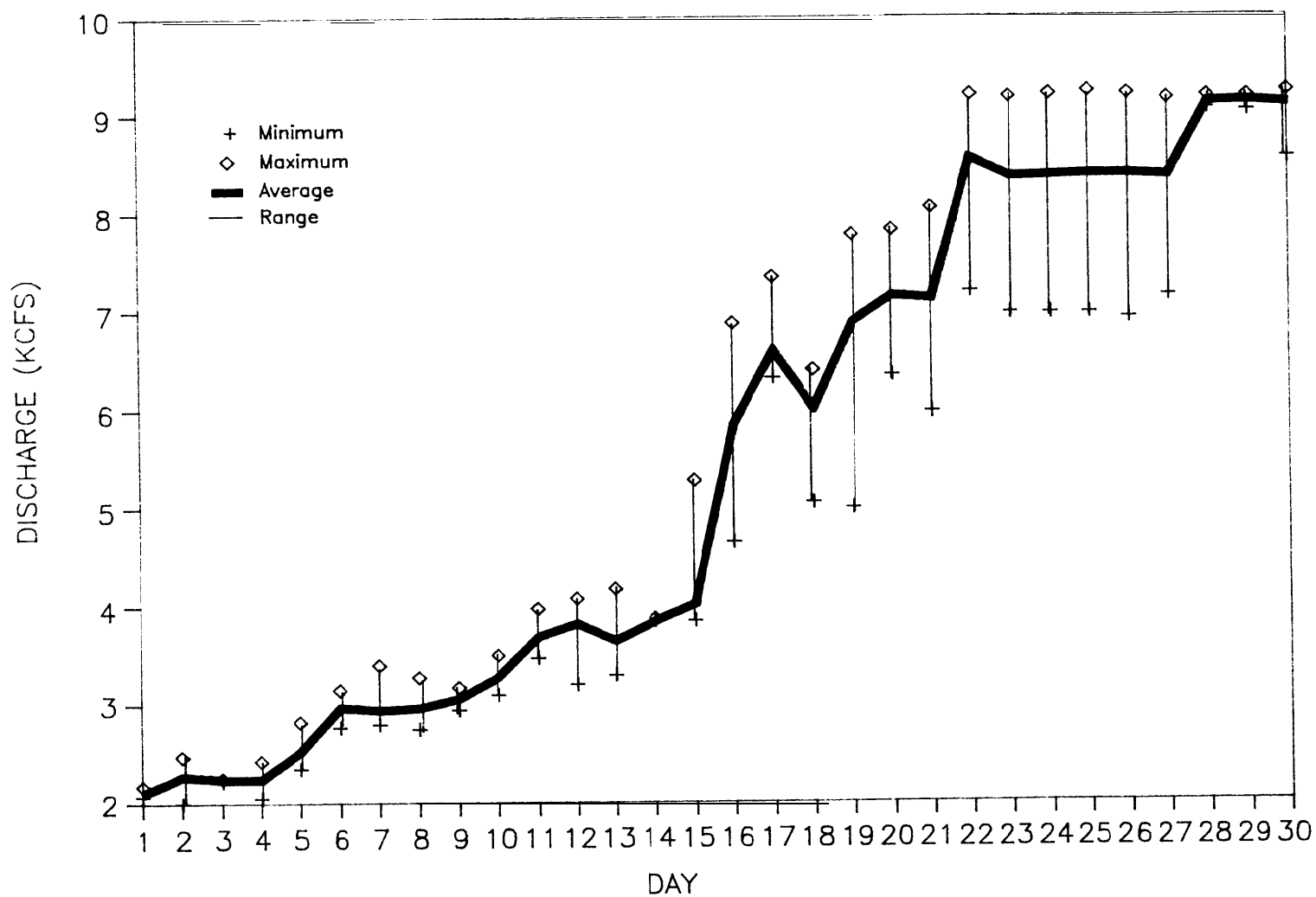


Figure C2. Average, minimum and maximum discharge from Dworshak Dam recorded by United States Army Corps of Engineers on the Northfork Clearwater River, November 1982 – 1985.

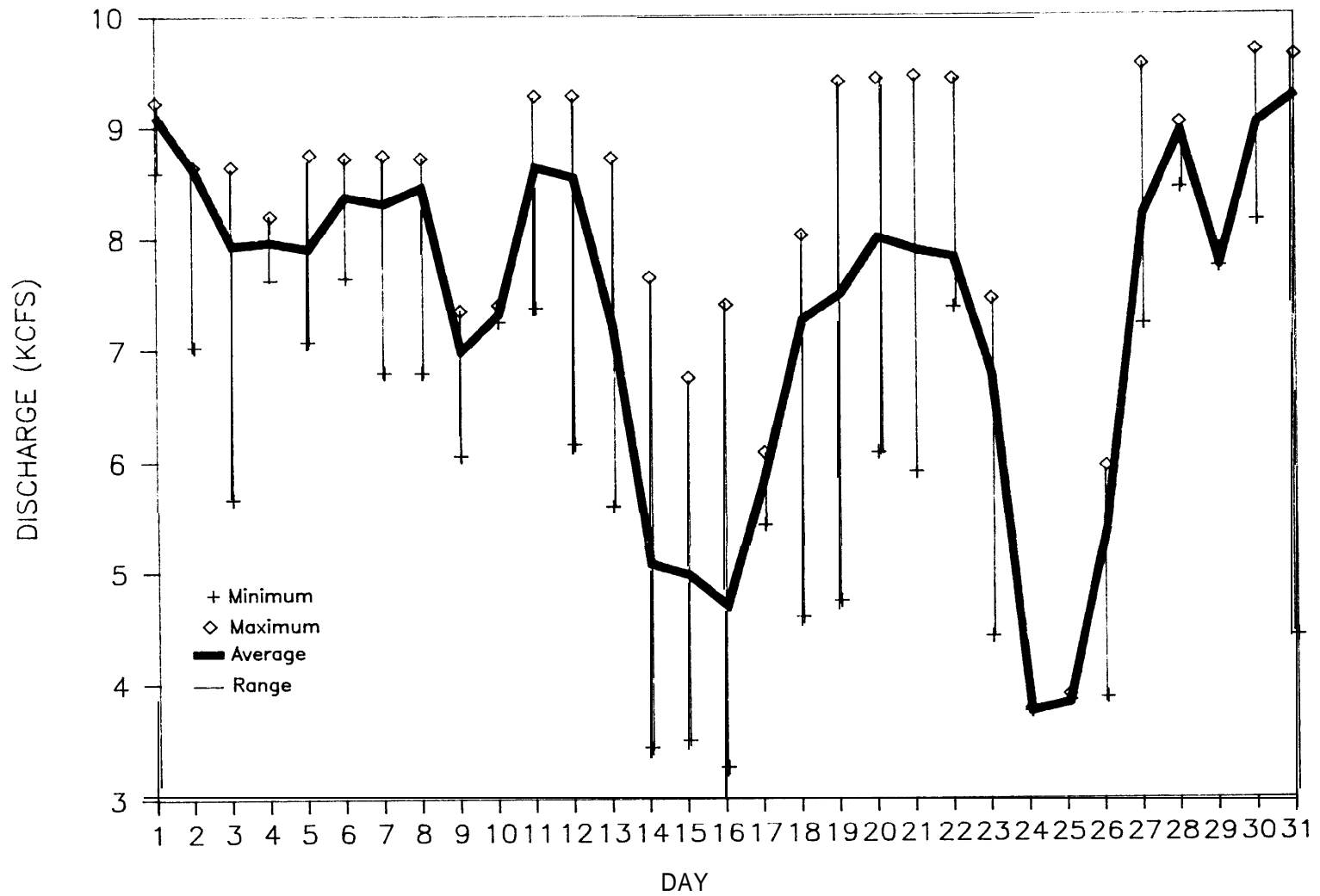


Figure C3. Average, Minimum and maximum discharge from Dworshak Dam recorded by the United States Corps of Engineers on the Northfork Clearwater River, December 1982 - 1985.

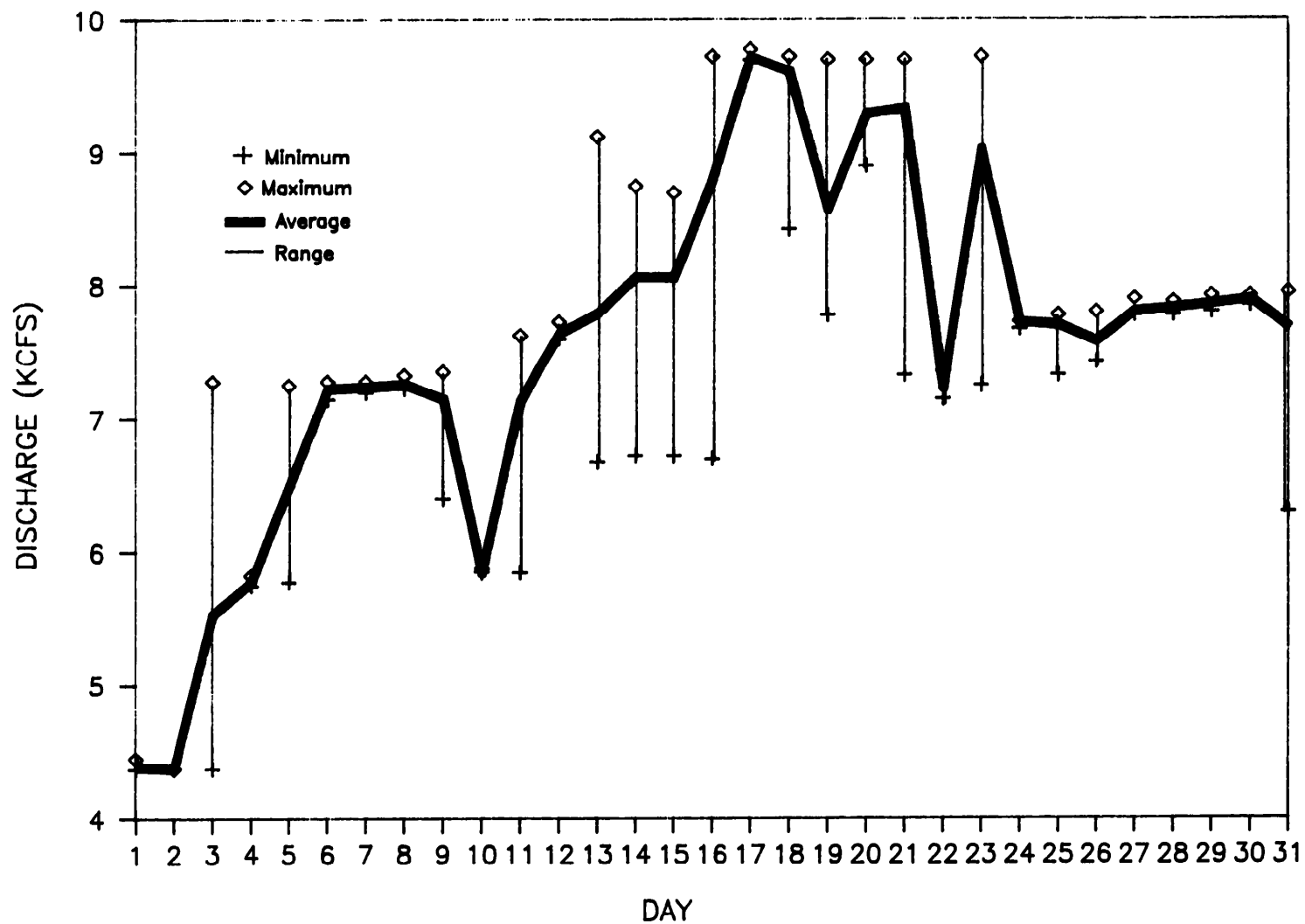


Figure C4. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, January 1982 – 1985.

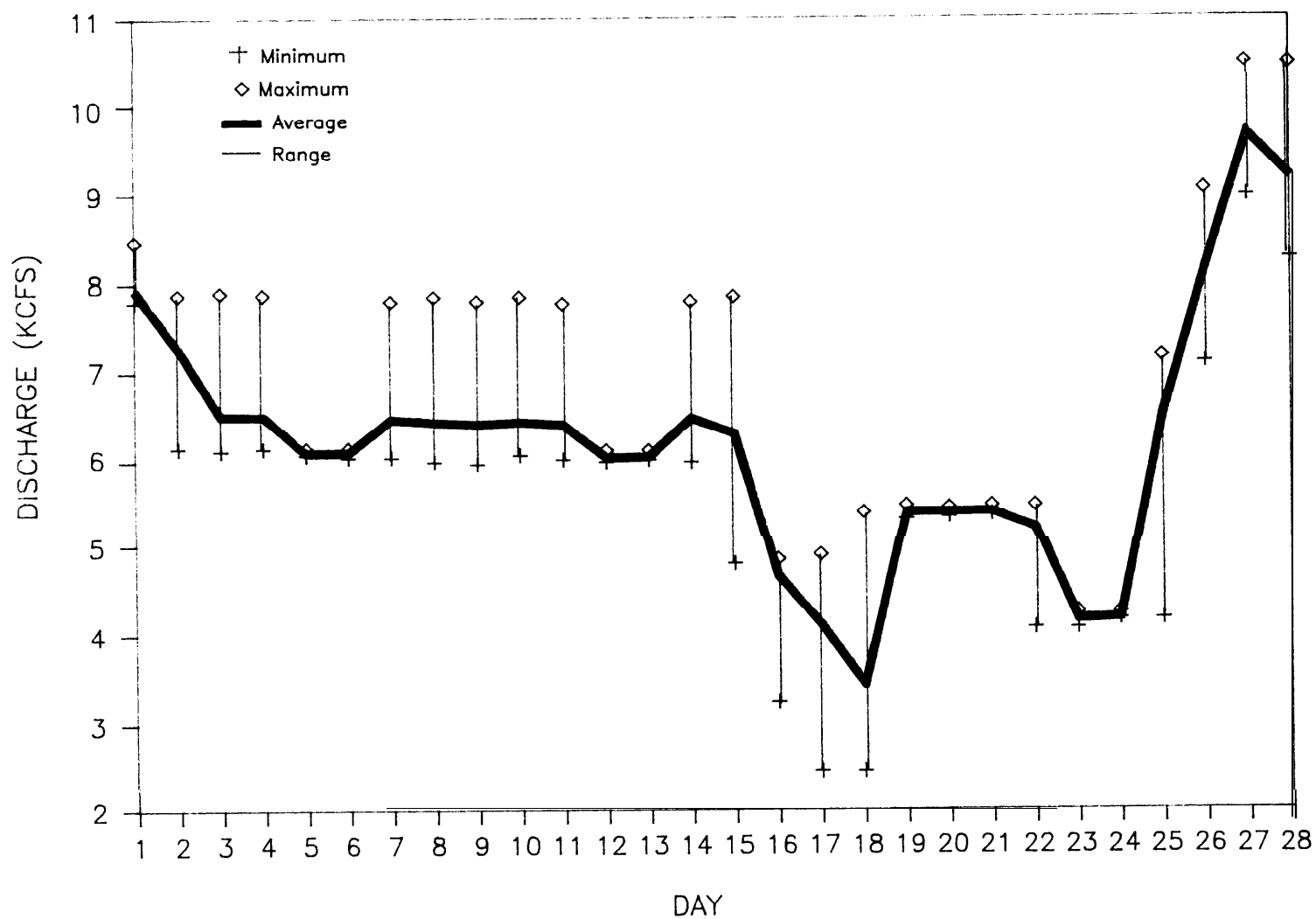


Figure C5. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, February 1982 - 1985.

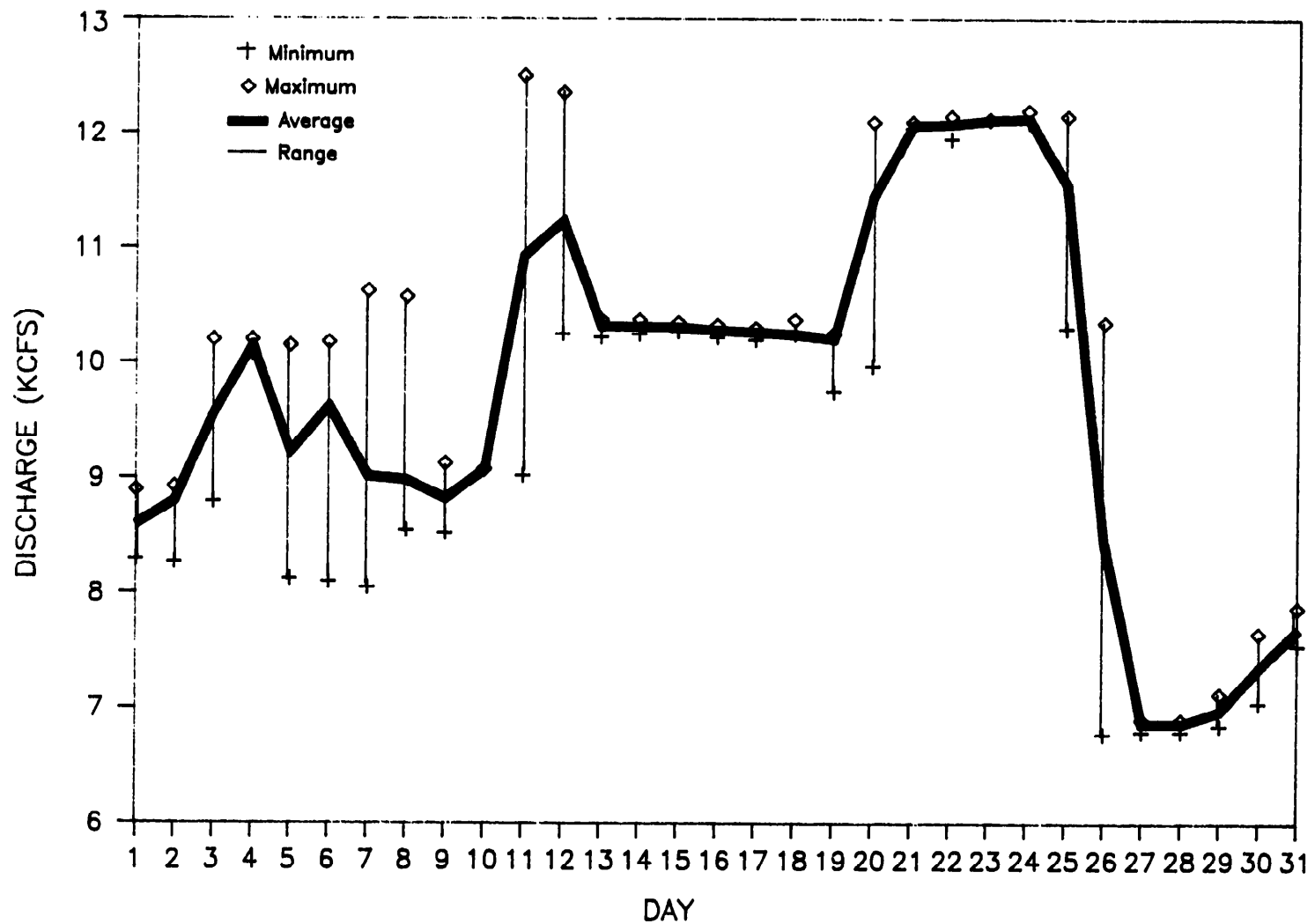


Figure C6. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, March 1982 – 1985.

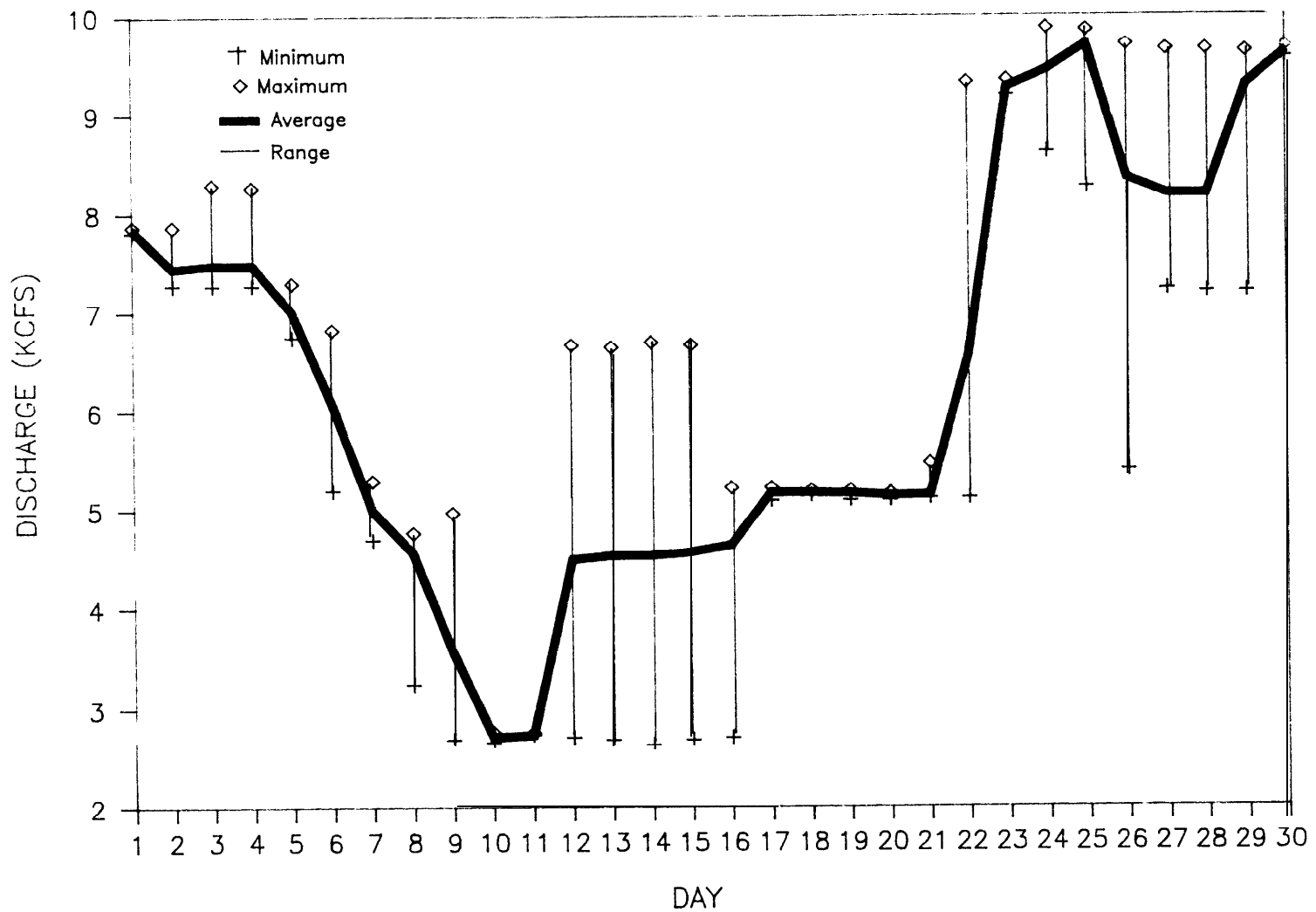


Figure C7. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, April 1982 - 1985.

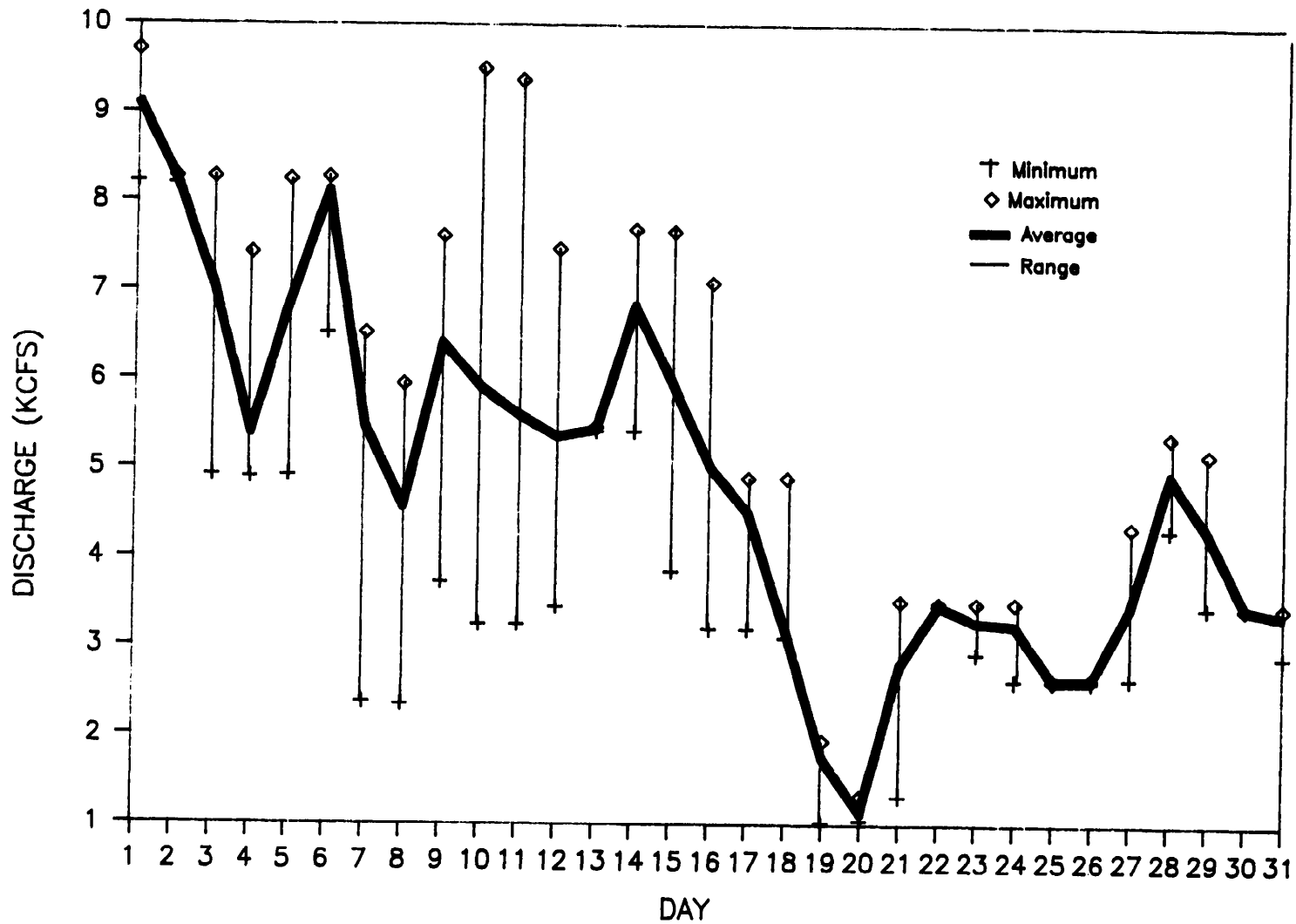


Figure C8. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, May 1982 – 1985.

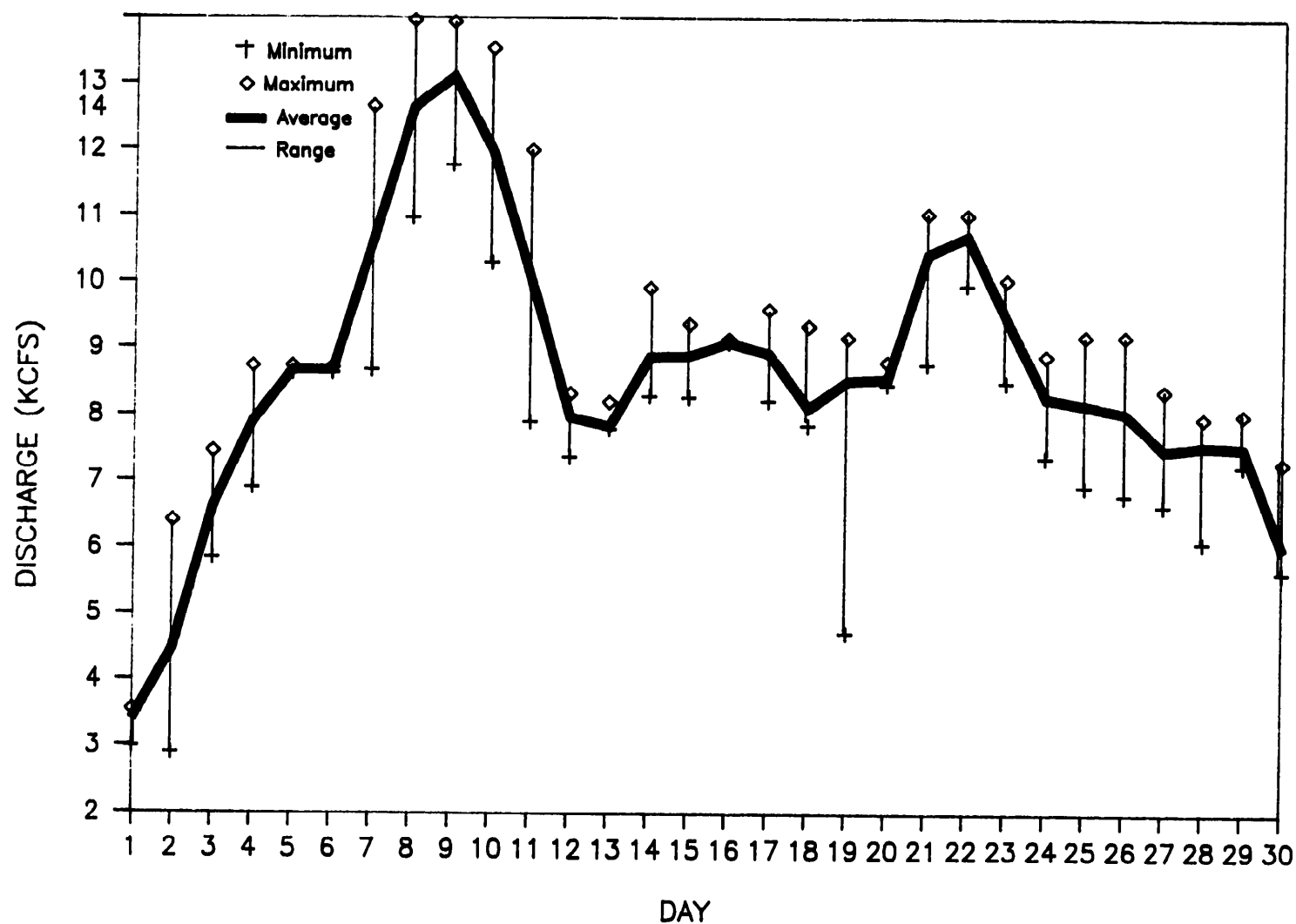


Figure C9. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, June 1982 – 1985.

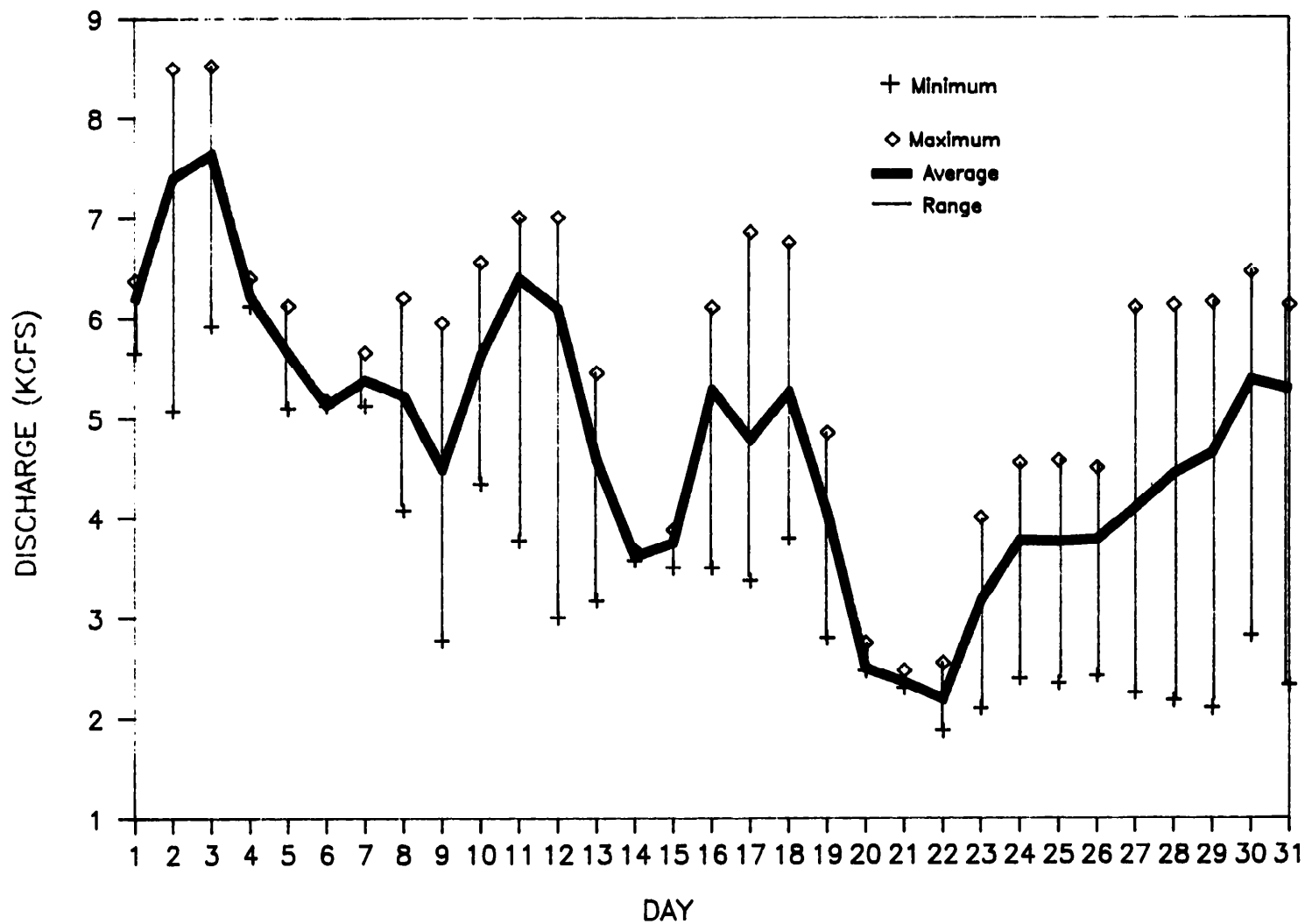


Figure C10. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, July 1982 – 1985.

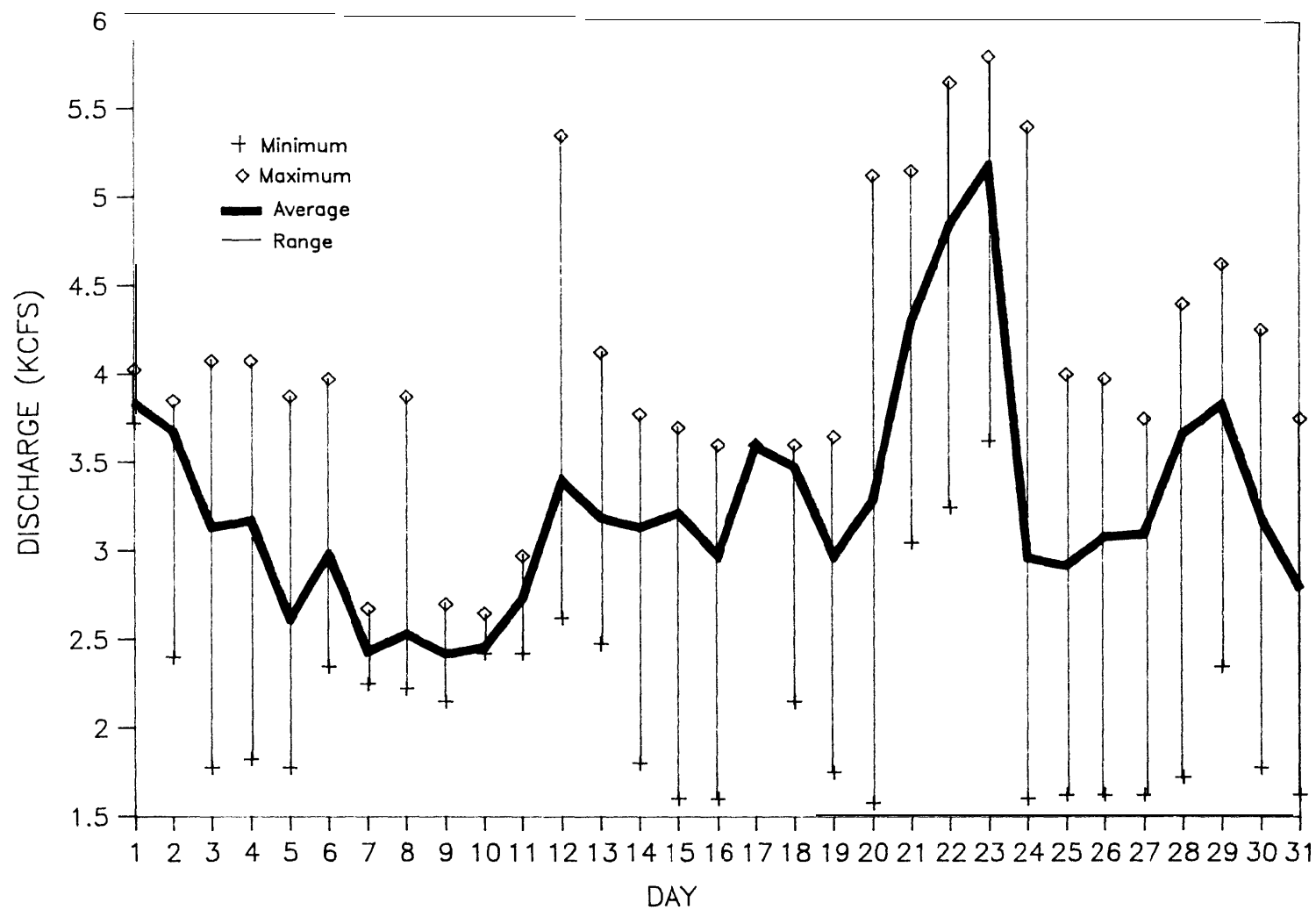


Figure C11. Average, minimum, and maximum daily discharge from Dworshak Dam recorded by the United States Army Corps of Engineers on the Northfork Clearwater River, August 1982 –1985.

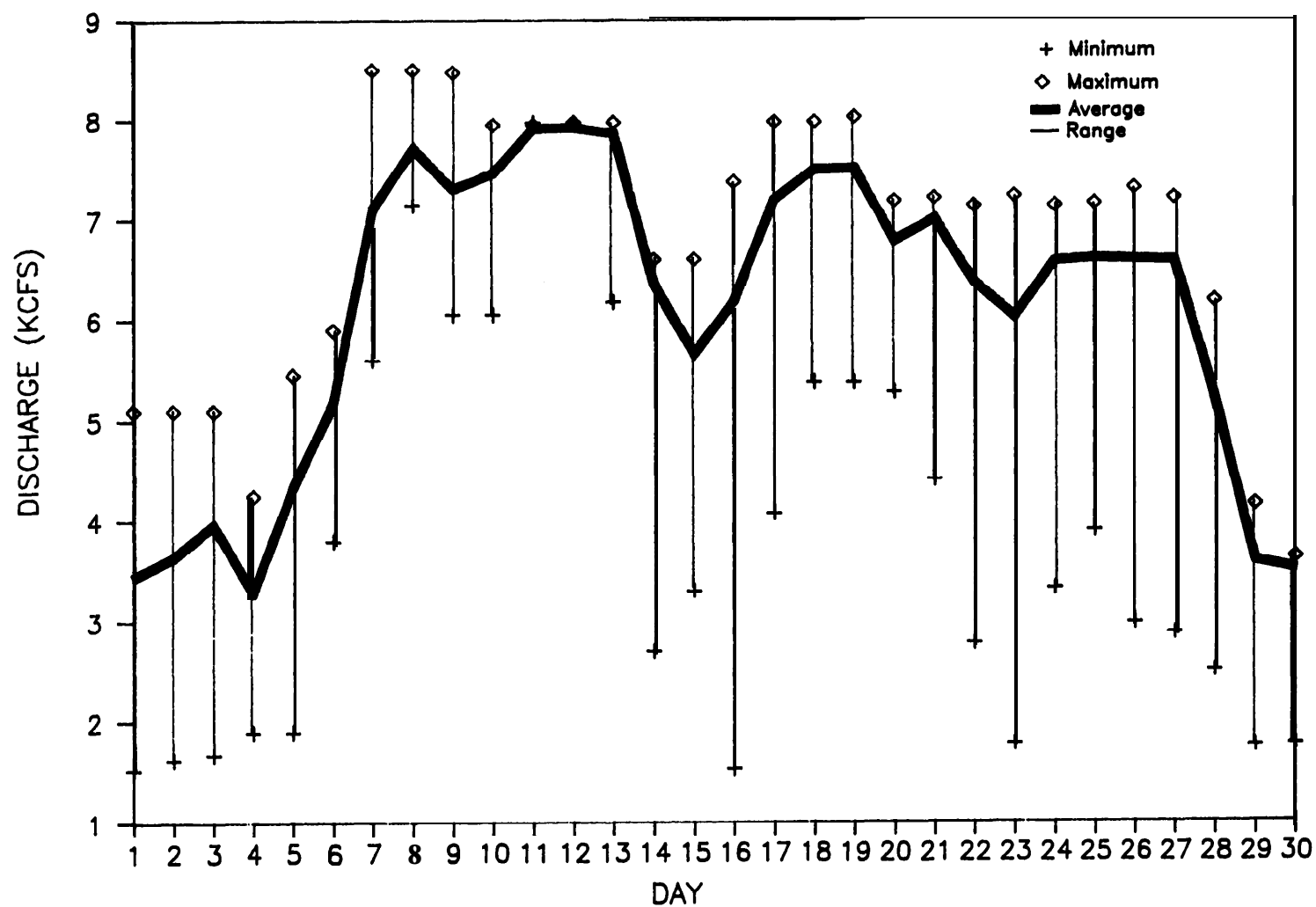


Figure C12. Average, minimum and maximum discharge from Dworshak Dam recorded by the United States Corps of Engineers on the Northfork Clearwater River, September 1982 - 1985.

APPENDIX D

Task 5. Conduct a review and analysis of the potential costs and benefits to be obtained from outplanting salmonids in the lower Clearwater River.

Jeff Gislason (personal communication) explained that the purpose of this task was to calculate how much it would cost to outplant enough smolts to get 100 adult fall chinook back to the LMCR. We accomplished this task by contacting Paul Seidell of the Washington Department of Fish and Game to acquire Snake River fall chinook total rearing costs and smolt to adult survival to Lyons Ferry Hatchery. We assumed that if the adults had to negotiate Little Goose and Lower Granite Dams there would be an additional 30% mortality by the time the fish reached the LMCR (i.e. if 143 adults survive to Lyons Ferry 43 would die passing over Little Goose and Lower Granite Dams). The calculations that follow were made for age-0 fry and age 1+ smolt releases with adult hatchery escapement rates of .25% and 1.5%, respectively. Adult hatchery escapement rates of .50% and 4.0% for age-0 and age 1+ respectively, were also used in calculations to provide for increased fish survival with improved dam passage. Total rearing costs to fry/smolt release average \$2.50/lb.

Age-0 Release:

$$\begin{aligned}\text{Number of fry } (.0025) &= 143 \text{ fish returned} \\ \text{Number of fry} &= 143/.0025 \\ \text{Number of fry} &= 57,200\end{aligned}$$

so: (57,200 fry)(1lb./75 fry) (\$2.50/lb.) = \$1,907

$$\begin{aligned}\text{Number of fry } (.005) &= 143 \text{ fish returned} \\ \text{Number of fry} &= 143/.005 \\ \text{Number of fry} &= 28,600\end{aligned}$$

so: (28,600 fry)(1lb./75 fry) (\$2.50/lb.) = \$953

Age-1+ Release:

$$\begin{aligned}\text{Number of smolts } (.015) &= 143 \text{ fish returned} \\ \text{Number of smolts} &= 143/.015 \\ \text{Number of smolts} &= 9,533\end{aligned}$$

so: (9,533 smolts) (1lb./6 smolts)(\$250/lb.) = \$3,972

$$\begin{aligned}\text{Number of smolts } (.04) &= 143 \text{ fish returned} \\ \text{Number of smolts} &= 143/.04 \\ \text{Number of smolts} &= 3,575\end{aligned}$$

so: (3,575 smolts) (1lb./6 smolts)(\$2.50/lb.) = \$1,489

Therefore, if we were to set an escapement goal of 10,000 fish to the Clearwater River for 1991 (assuming fish would return as 3 salts) we would incur costs in the following range.

Age-0 Release (.25% adult escapement to hatchery):

\$1,907/100 adults = X\$/10,000 adults

so: A 10,000 fish escapement would cost \$190,700

Age-0 Release (.50% adult escapement to hatchery):

\$953/100 adults = X\$/10,000 adults

so: A 10,000 fish escapement would cost \$95,300

Age-1+ Release (2.0% adult escapement to hatchery):

\$3,972/100 adults = X\$/10,000 adults

so: A 10,000 fish escapement would cost \$397,200

Age-1+ Release (4.0% adult escapement to hatchery):

\$1,489/100 adults = X\$/10,000 adults

so: A 10,000 fish escapement would cost \$148,900

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